Solar and Planetary Physics and Motion

Preliminary Chapters

EDWARD LYNCH

LIBRARY OF CONGRESS

COPYRIGHT OFFICE

WASHINGTON, D. C.

DEAR SIR :

In compliance with your request we send herewith inclosed

No. 20 B

LIBRARY OF CONGRESS

COPYRIGHT OFFICE

WASHINGTON, D. C.

DEAR SIR :

In compliance with your request we send herewith inclosed the certified document noted below.

The amount stated below has been applied to cover the statutory fee for certified copy of record.

Remittance received, $ 1.00

Fee applied, $ 1.00

Excess remittance returned herewith by check on the Treasurer of the United States, $..............

Fee applied and charged to the balance in hand from your trust fund, $..............

Respectfully,

Thorvald Solberg
Register of Copyrights.

INCLOSURES:
1 Certified doc. Class A xxc No. 19574 9
Refund check, $............

Mr Edward Lynch,
449 North Mentor ave.,
Pasadena, Calif.

Circular Letter 20 B
SUBJECT:
Certified Documents
July 1927,—1,000

CLASS a XXc. No. 195749

Library of Congress, to wit:

Be it remembered,

That on the second *day of* January *, 19*08*,*
Edward Lynch *, of*
Alameda, Cal. *, ha* th *deposited in this Office the title*
of a Book

the title of which is in the following words, to wit:

Solar and Planetary Physics and Motion. Preliminary Chapters

the right whereof he *claim* s *as author and proprietor in conformity with the laws of the United States respecting Copyrights.*

Office of the Register of Copyrights,
Washington, D. C.

Herbert Putnam
Librarian of Congress

By

Thorvald Solberg
Register of Copyrights.

I hereby certify that the foregoing is a true copy of the original record of copyright. In witness whereof, *the seal of this Office has been hereto affixed this* twenty-first *day of* December *, 19*28.

Thorvald Solberg
Register of Copyrights

Copyright Office of the United States of America,
Washington, D. C.

Solar and Planetary Physics and Motion

Preliminary Chapters

EDWARD LYNCH

"To the Stars Through Difficulties"

In Memory of

Dr. John M. Gregory

First President of

The University of Illinois

These pages are Dedicated

Gift of Mrs HH Lynch

PREFACE.

The economic value of a sure basis of prediction in meteorology is inestimable. The value to the nation of a reliable forecast of the season, of probable rain supply, of drouths, of extraordinary degrees of heat or cold, weeks or even months in advance of the events, cannot be estimated in money. Weather bureau experts and other scientific men have labored long in search for a periodic law of recurrence of weather conditions. Publications by thousands have been issued tabulating results of careful research into past weather conditions.

The sun and its constitution is the final physical cause of all conditions which make life sustainable on the earth. The sun has been subjected to every possible form of scrutiny in the endeavor to understand the laws of its being and the causes of its manifest variability.

This is another attempt. I am persuaded that the tables given herein summarize a law of periodic solar action which will render prediction of future solar action precise as to time and definite as to intensity. These tables are based entirely upon rigorous calculations of events and facts open to the scrutiny of all. Personal bias and vanity can not sway the results.

If the writer is mistaken in this statement then those tables present the most remarkable combination of figures and fiction, extending over 300 years, to be found in the history of mathematics. So chameleon like are the figured results of planetary action that they simulate the precise form and physical conditions, as to time and intensity, of solar storm and calm: and they seem to truthfully reflect every well established rule of solar action derived from observations extending over 300 years. Spots come and go on the sun at irregular intervals: no two periods of maxima or minima occur of equal length in succession nor indeed at all. Yet these tables, *derived merely from the motions of the planets and the sun*, follow these spot conditions, through all their sinuosities, telling of the waxing and waning of solar activity as if they were derived from close scrutiny of that condition.

Certainly, therefore, if these pages do not tell the truth they are most interesting fiction, and are illustrative of the ability of plausible figures to lie.

EDWARD LYNCH.

1330 Caroline Street, Alameda, California, October 8th, 1907.

A PRELIMINARY CHAPTER ON SOLAR PHYSICS.

The object of this chapter is to briefly state a theory, founded upon a broad basis of fact, of the causes of solar activity; especially dealing with the periodicity of sun-spots, because the knowledge of the periodical variation of sun-spots is the most definite and extended, covering three hundred years of the sun's history.

This theory rests upon a new and more extended examination of the effects of gravitation by the great planets upon the sun, especially upon its movement towards its apex.

The activity of the sun is manifested *directly* by its spot periods, its coronas, and its variable shape; and, *indirectly,* by terrestrial phenomena which happen at the same time with solar disturbance, namely, periodical variation in magnetic declination, aurora borealis, extraordinary heat, cold, and wind and electrical storms. In addition I will at some future time publish detailed reasons for including some kinds of earthquakes in this list of effects indirectly manifested, giving merely a sketch at this time. A brief summary of the present state of learning as to the causes of solar activity and the present theories, based upon observation, of its effects is necessary to the introduction of this chapter.

In 1903 Miss Clerke published "Problems in Astrophysics," in which she said:

"The sun is subject to a rhythmical tide of disturbance, ebbing and flowing in about eleven years. But the flow is irregular and spasmodic. Both the intensity of the crises and the intervals at which they recur vary largely and unaccountably. Probably the eleven year cycle is involved in others. One, there is reason to believe, brings about alternate accentuations and partial effacements of change comprised within a term of some sixty-five years. And minor pulsations—wavelets on the great rollers—are besides evident. Prediction nevertheless remains at fault. Spot maxima are delayed or anticipated, they are lanquid or energetic, as the outcome of modes of action defying calculation. * * * The error of the spot period may amount to nearly half its normal length. Thus sixteen years elapsed between the maximum of 1788 and the next certainly ensuing, and only 7.3 years separated the culminating points in 1829.9 and 1837.2 * * *

"The throbbings of solar agitation affect his entire system. In how many ways, and by what hidden means, we can but vaguely surmise. Terrestrial meteorology, as a whole, is certainly embraced in the great cycle, although the details of its conformity baffle by their intricacy, the most painstaking pursuit. * * *

"A prolonged solar calm appears to have set in about 1643. Galileo and Scheiner had been at no loss for subjects of study; but the diligence of their successors, although unrelaxed, went mostly unrequited. * * *

"Definitively the protracted minimum came to an end in 1716 and there was a normal maximum in 1718. * * *

"Individual outbreaks on the sun are often unmistakably associated with commotions of the magnetic system. These so called 'storms' are world wide in their nature, abrupt in their origin, and bear witness to some *vital* spasm attacking the globe as a whole, and at once. * * *

"Little progress has been made towards ascertaining the cause of solar periodicity. We are only assured that it is not imposed from without, but arises from within; it resembles a 'free' rather than a 'forced vibration.' This conclusion, it is true, tends to relegate the matter to obscurity for the interior of the sun is terra incognita and seems likely to remain so. His cyclical changes may belong to his original constitution; they may date from nebular times, and be as inherent as the tone of a bell. Or they may simply characterize a change of growth, and prove liable to modification and effacement." (pp. 151-160.)

In another of her works Miss Clerke says:

"The idea that solar maculation depends in some way upon the position of the planets occurred to Galileo in 1612 (citing Opere, t. iii, p. 412). It has been industriously sifted by a whole bevy of modern solar physicists. Wolf in 1859 found reason to believe that the eleven year curve is determined by the action of Jupiter, modified by that of Saturn, and diversified by influences proceeding from the earth and Venus. "Its tempting approach to agreement with Jupiter's period of revolution round the sun, indeed, irresistibly suggested a causal connection; yet it does not seem that the most skilful 'coaxing' of figures can bring about a fundamental harmony. Carrington pointed out in 1863, that while, during *eight successive periods,* from 1770 downwards, there were approximate coincidences between Jupiter's aphelion pasages and sun-spot maxima, the relation had been almost exactly reversed in the two periods preceding that date"(citing Observations at Redhill, p. 248): "and the latest conclusion of M. Wolf himself is that the Jovian origin must be abandoned." (Citing Compte's Rendus, t. xcv, p. 1249.)

"M. Duponchel of Paris was nevertheless not wholly unsuccessful in accommodating discrepancies with the help of perturbations by the large exterior planets; since his prediction of an abnormal lengthening of the maximum of 1883-4 *through certain peculiarities in the position of Uranus and Neptune* about the time it fell due, was partially verified by the event. (Citing Compte's Rendus, t. xciii, p. 827, t. xcvi, p. 1418.)"—*Clerke's Hist. of Ast., 3rd Ed., p. 202; 4th Ed., p. 163.*

In 1859 Dr. R. Wolf presented a formula by which the frequency of spots is connected with the motions of Venus, the earth, Jupiter and Saturn, and apparently exhibited a drawing showing these planets in conjunction and at ninety degrees from each other. ("Source and mode of solar energy." Heysinger, p. 108.)

William J. S. Lockyer sums up Dr. Wolf's sun-spot period theory as follows:

"Dr. Wolf was careful to point out that it was only the *mean length* of the solar period that covered a period of 11$\frac{1}{9}$ years, and *that the real length of any one period might differ from this value by as much as two years.* * * *

"His attention was also drawn to the fact that the times of maxima did not occur a constant number of years after a preceding minimum, and he was led to determine the *mean* time of occurrence of the maximum and of the minimum after the preceding maximum, by giving the *mean* intervals as 4.5 and 6.5 years respectively.

"Further he at first concluded that the total spotted area for each period was nearly constant, but, as he later remarks (Astron. Mittheil, 1876, p. 47 et seq.) this view could not be held, as these quantities not only varied but indicated 'eine bestimme Gesetz-mässigkeit.' *The length of the period of this variation he gave as about 178 years, which covered practically sixteen ordinary sun-spot periods* ('11.1111×16=177.7777').

"Somewhat later Dr. Wolf was led to suggest a shorter period of 55.5 years, which comprises about five ordinary eleven-year periods."—*Sci. Am. Supp. 24537, 24544, May 6-13, 1905.*

Miss Clerke again says:

"The further inclusion of recurring solar commotions within a cycle of fifty-five and a half years was simultaneously (1861) pointed out; and Hermann Fritz showed soon after that the aurora borealis is subject to an identical double periodicity (citing Wolf Mitth., No. XV, p. 107) Olmsted, following Hansteen, had already, in 1856, sought to establish an auroral period of sixty-five years. (Smithsonian Cont. Vol. VIII, p. 37.)

"The same inquirer detected besides, both for aurora and sun-spots, *a "secular period" of 222 years* (citing Hahn, p. 99, 1877) and the Kew Observations indicate for the latter oscillations accomplished within twenty-six and twenty-four days, depending most likely upon the rotation of the sun. (Citing Rept. Brit. Ass. 1881, p. 518; 1883, p. 418.)" *Clerke's Hist. Ast., 3rd Ed., p. 201; 4th Ed., p. 162.*

Professor Young says:

"Professor R. Wolf, of Zurich, has been especially indefatigable in his investigations upon this subject [periodicity of spots] and has succeeded in disinterring from all sorts of hiding places a nearly complete history of the solar surface for the past one hundred and fifty years. * * * and

with immense labor has combined them into a consistent whole, deducing a series of 'relative numbers' as he calls them, which represent the state of the sun as to spottedness for every year since 1745. * * * These relative numbers, as tested by the most recent photographic results of De La Rue and Stewart, are found to be approximately proportional to the area covered by the spots. We give on the opposite page a figure deduced from the numbers, published by Wolf in 1877 in the Memoirs of the Royed Astronomical Society and showing their course year by year since 1772. The horizontal divisions denote years, and the height of the curve at each point gives 'relative number' for the date in question. For example, in 1870, about the middle of the year, the relative number was 140, while early in 1879 it ran as low as 3." p. 147: * * * "Our diagram * * * only goes back to 1772, but Wolf's investigations reach to 1610, and he gives; in the paper from which were derived the numbers used in constructing our diagram the following important table of maxima and minima." (p. 147.) * * * (Here follows same table as is given by Miss Clerke hereinafter copied.)

"*There is no question of solar physics more interesting or important than that which concerns the cause of this periodicity*, but a satisfactory solution remains to be found. *It has been supposed by astronomers of very great authority that the influence of the planets in some way produces it. Jupiter, Venus and Mercury have been especially suspected of complicity in the matter*, the first on account of his enormous mass, the others on account of their proximity. De La Rue and Stewart deduce from their photographic observations of sun-spots between 1862 and 1866, a series of numbers, which strongly tend to prove that, when two of the powerful planets are nearly in line as seen from the sun then the spotted area is much increased. They have investigated especially *the combined effect of Mercury and Venus, Jupiter and Venus, and Jupiter and Mercury* as also the effect of Mercury's approach to, or recession from, the sun. In all four cases there seems to be a somewhat regular progression of numbers, though much less decided in the third and fourth than in the first and second. The irregular variations of the numbers are, however, so large and the duration of the observations so short, that it is hardly safe to build heavily upon the observed coincidences, since they may be merely accidental. An attempt to connect the eleven-year period with that of the planet Jupiter also breaks down. While, for a certain portion of the time, there is a pretty good agreement between the sun-spot curve and that which represents the varying distance of Jupiter from the sun, there is complete discordance elsewhere. About 1870 the maximum spottedness occurred when the planet was *nearest* the sun, but at the beginning of the century the reverse was the case. Loomis (who is in favor of inserting a sun-spot maximum in 1794, and, on this hypothesis, deduces a mean sun-spot period of 10 years in place of 11.1) suggests that

the conjunctions and oppositions of Jupiter and Saturn may be at the bottom of the matter,. These occur at intervals of 9.93 years, from a conjunction to an opposition, or vice versa. But, when we come to test the matter, we find that, in some cases, sun-spot minima have coincided with this allineation of the two planets; in other cases, maxima.

"*It is indeed, very difficult to conceive in what manner the planets, so small and so remote, can possibly produce such profound and extensive disturbances on the sun.* It is hardly possible that their gravitation can be the agent, since the tide raising power of Venus upon the solar surface would be only about $\frac{1}{750}$ of that which the sun exerts upon the earth; and in the case of Mercury and Jupiter the effect would be still less, or about $\frac{1}{1000}$ of the sun's influence on the earth.

"The sun (apart from the moon) raises a tide on the deep waters of the earth's equator, something less than a foot in elevation, so that, making all allowances for the rarity of the materials which compose the photosphere, it is quite evident that no planet lifted tides can directly account for the phenomena. If the sun-spots are due in any way to planetary action, this action must be that of some different and far more subtle influence."—*Young, 149 to 151, Sun, Aug. 1st, 1881.*

Chambers says:

"That the period is clearly an eleven-year one, as has already been stated; (2) that it is not, however, quite as simple in its form as it was at first thought to be; for in reality there are two periods superposed, the one rather more than half a century long, and the other extending over the eleven years already spoken of. *We do not possess early observations sufficiently numerous and sufficiently good to enable us to draw any unimpeachable conclusions as to the nature of the long period;* we can only be certain that it exists. The later labors of Wolf, however, fixed that period at 55½ years. It is a result of this that, according to Loomis, a period of comparative calm on the sun existed between 1810 and 1825.

"Each maximum lies nearer to the minimum which precedes it than to the minimum which follows it, for the spots increase during 3.7 years and diminish during 7.4 years. According to De La Rue the increase occupies 3.52 years and diminution 7.55 years. This concurrence between De La Rue and Wolf is surprising considering the diversity of the methods which led to results almost identical, the one set being based on the number of spots, and the other on the superficial extent of the spots. * * *

"The presence of spots only in Zodiacal regions *led Galileo to suspect the existence of some relations between the spots and the position of the planets; but there is in this a mere surmise, which when it was made, had nothing to justify it,* and it is still impossible for us to say anything for certain on the point.

"*According to Wolf, the attraction of the planets or some of them, is the real cause of the periodicity which we are dealing with;* that attraction producing on the surface of the solar globe true tides, which give birth to the spots, these tides themselves experiencing periodic variations owing to the periodic changes of position of the celestial bodies which cause them. It has even been thought safe to assert that the fact of the principal period coinciding with the revolution of Jupiter is of momentous significance; but this coincidence seems purely accidental, and no certain conclusion can be drawn as to this matter. The influence of Mercury and Venus would perhaps be much more potent, for their distance from the sun is not very great, and this should render their influence more sensible. On the other hand their masses appear to be too small to be capable of producing any sufficient effect.

"De La Rue, Balfour Stewart, and Löwy most perserveringly studied this point of solar physics. *They seem to have arrived at the conclusion that the conjunctions of Venus and Jupiter do exercise a certain amount of influence* on the number of spots and on their latitude; and that this influence is less considerable when Venus is situated in the plane of the solar equator. At any rate it is a fact that a great number of the visible inequalities in a duly plotted curve of the spots do really correspond to special positions of these two planets.

"In order to determine with more precision these coincidences and the importance which attaches to them, De La Rue extended his inquiries. He separately analyzed many different groups of spots, selecting for his purpose more particularly those of which the observations happened to have been specially continuous and complete, giving a preference moreover to those which had been observed in the central portions of the sun's disc. From an investigation of 794 groups De La Rue arrived at the following conclusions: (1) If we take a meridian passing through the middle of the disc and represented by a diameter perpendicular to the equator, we find that the mean size of the spots is not the same with regard to that meridian. It appears certain that the correction required for perspective does not suffice to explain this difference; and that another element must be introduced in order to secure that the apparent dimensions of the spots may be the same on both sides. We do not yet possess a very clear explanation of this fact; but the most probable is this:—that the spots are surrounded by a project-

ing bank, which seems to disappear in part during their transit across the sun. This bank is more elevated on the preceding than on the following side; accordingly the spots ought to seem smaller when they are in the eastern half of the disc larger when they are in the western half; for in the first position the observer's eye meets an elevated obstacle, which hides a portion of the spot itself. (2) De La Rue specially studied the spots observed at the times when the planets Venus and Mars were at a heliocentric distance from the earth equal to 0, 90, 180 and 270 degrees, and arrived at this result; the spots are larger in the part of the sun which is away from Venus and Mars, and they are smaller on the side on which these planets happen to be. The same result was obtained, whether Carrington's figures or the Kew photographs were employed. (3) Meanwhile it does not appear that Jupiter emits any similar influence. This influence should be easily perceived, for if we calculate the action of the planets in the way that we calculate the tides, treating it as directly proportional to the masses and inversely proportional to the cubes of the distances, the influence of Jupiter should greatly outweigh that of Venus.

"Wolf thought he had noticed traces of some influence being exerted by Saturn, but this remains altogether without confirmation.

"De La Rue noticed that large spots are generally situated at extremities of the same diameter. This law also often applies to the development of large prominences. The coincidence agrees well with the theory that there exists on the sun some action resembling that of our tides."—Story of the Solar System, Chambers, p. 51 et seq., Appleton, N. Y., 1904.

Flammarion takes up the argument based on the influence of Jupiter and disposes of it as follows:

"What may be the cause of this motion of the solar surface?

"This cause may be in the interior of the sun. It might also be exterior to him.

"If it is in the interior of the solar body, it would not be easily discovered.

"If it be exterior, the first idea which suggests itself is to seek for it in some combination of planetary motions.

"Among the different planets of the system there is one which, from its importance, first presents itself to us, and it is found that the duration of its revolution round the sun approaches closely to the preceding period. Our readers have already named Jupiter, of which the diameter is only ten times smaller than that of the solar colossus, and of which the mass is equivalent to a thousandth of that of the central star. It revolves round the sun in 11.85 years.

"During the course of its revolution its distance from the sun is subject to a perceptible variation. This distance, which is, on the average 5.203 (that of the earth being one) sinks at the perihelion to 4.950 and rises at the aphelion to 5.456. The difference between the perihelion and aphelion dis-

tance is 0.506—that is to say, a little more than half the distance from the earth to the sun, or about 47 millions of miles. This is rather considerable. Revolving thus round the sun, Jupiter exercises on him an attraction easily calculated, and constantly displaces his center of gravity, which can, consequently, never coincide with the center of figure of the solar sphere, and is always found drawn eccentrically towards Jupiter. The attraction of the other planets prevents this action from being regular, but it can not prevent it from being predominant.

"It might be thought that this motion of the solar mass should be interpreted for us by the spots, and that it might have, for example, a maximum of spots when Jupiter attracts more, or attracts less, the solar center. If we had here the cause of the periodicity of the spots, this periodicity should be 11.85 years. But it is shorter. While Jupiter returns to his perihelion only after 11.85 years, the maximum of spots returns very irregularly, but on the average after 11.11 years—that is to say, 74 hundredths of a year or 270 days sooner. This number comes from a discussion of all the observations. Does there exist in the solar system a second cause which obliges a phenomenon to advance thus on the perihelion of Jupiter? Venus revolves round the sun in 225 days, and about every 225 days meets the radius vector of Jupiter. The earth revolves in 365 days, and meets the radius vector of Jupiter every 399 days. These two planets certainly act on the sun in the same way as the giant planets, but with less intensity. If this common action were expressed by an increase of spots we should see in the fluctuations of the solar spots combinatons of the period of 11.85 of Jupiter with that of one year for the earth, of 0.62 for Venus, and of 0.24 for Mercury. Unfortunately, this combination does not appear to produce the observed effect.

"Whether it be the perihelion or the aphelion of Jupiter which causes the maximum of solar spots, these maxima should always coincide with the same positions. But, on the contrary, each revolution of Jupiter adds the difference of 0.74 which we have just noticed, and at the end of a certain time, of thirteen to fourteen revolutions, the positions are reversed. We must, then, although with regret, give up Jupiter.

"Whatever may be the relation which exists between the two periods, the connection is, then, purely accidental, for we cannot logically admit that the same causes produce contrary effects and that the perihelion sometimes induces a minimum and sometimes a maximum.

"However let us dismiss the idea of the variation of the distance of Jupiter and consider only its imaginary circular revolution. Let us suppose that the variation of distance does not act perceptibly. The fact still remains that Jovian attraction makes the center of gravity turn round his center of figure in 11.85 years. Are the spots always on the radius vector of

Jupiter? No, the earth crosses this radius vector every thirteen months, and we do not see more spots on that solar hemisphere than on the opposite hemisphere. Moreover the sun rotates on itself in 26 days and would bring these spots in view of the earth, since they turn with the solar surface. Under whatever aspect we discuss the question, we are, then, led, in spite of ourselves, to eliminate the action of Jupiter. It is the same and with much stronger reason as regards all the other planets.

"It is difficult to conceive how the planets which are so small and so distant could produce in the sun disturbances so profound and so extensive. It is scarcely possible that it should be their gravitation which acts, considering that the attractive power of Venus on the solar surface would be about $\frac{1}{750}$ of that which the sun exercises on the earth; and in the case of Mercury and Jupiter the effect would be still less, about $\frac{1}{1000}$ of the influence of the sun on the earth. The sun, considered apart from the moon, raises on the deep waters at the earth's equator a tide of a little less than 13 inches in height, so that, taking into account the rarefaction of the substance of which the photosphere is composed, it is very evident that any tide produced by a planet can not directly explain the phenomena. If the solar spots are due in any way to planetary action, this action must be that of a different and much more subtle influence."—*Flammarion Pop. Ast., pp. 285-287.*

These authors summarize the efforts of astronomers to ascertain *the causes* of the sun-spots and of their waxing and waning and of the efforts to connect therewith the movements of some of the planets. It has been shown that, beginning with Galileo and down to the efforts of De La Rue, Stewart and Lowe, they partially examined for brief periods the effects upon the motion of the sun of some of the planets, and abandoned their efforts because they thought that the planets were too small and remote; and, that such influences were inadequate and indeterminate as a cause.

I present herein some facts and tabulated calculations based upon long periods of time—28 centuries—to show that a sufficient physical cause of the sun's disturbance is to be found in the movements and attraction of the four great planets Jupiter, Saturn, Uranus and Neptune; and that the physical disturbance of the mass and motion of the sun by the mass and motion of those planets is synchronous with and proportionately variable with all of the observed solar and terrestrial phenomena for which solar action is now held responsible. That as the mass and motion of the planets is concentrated in one direction upon the sun its excitement reaches a maximum; and as their masses and motions are dispersed that excitement is allayed and reaches a minimum; and that such concentration and dispersion coincides in time and force with the facts reached by induction from observations upon sun-spots, prominences, auroras, coronas, magnetic declination, change of form of the sun, and other effects of solar activity.

R. A. Proctor gave the physical effects of the planets upon the sun in his "Old and New Astronomy" as follows:

"(713): The sun's mass so enormously exceeds that of all the planets taken together, that he is capable of swaying their motion without being himself disturbed. He is not indeed quite fixed. We know from Newton's third law that whatever force the sun exerts on any planet, the planet exerts precisely the same force on him; but then he is so massive that the pull which compels a planet to circle round the sun displaces him very slightly." [In a note to this he says:]

"Not, however, quite so slightly as Sir John Herschel asserts in the following oft-quoted passage:

"If he pulls the planets, they pull him and each other; but such family struggles affect him but little. *They amuse them* he proceeds quaintly, but don't disturb him. As all the gods in the ancient mythology hung dangling from and tugging at the golden chain which linked them to the throne of Jove, but without power to draw him from his seat, so, if all the planets were in one straight line and exerting their joint attractions, the sun—leaning a litttle back as it were to resist their force—would not be disturbed by a space equal to his own radius; and the fixed center, or, as an engineer would call it, the center of gravity of our system, would lie still far within the sun's globe."

Proctor proceeds as follows:

"The distance of the center of gravity of the whole row of bodies from the sun's center can, of course, be easily determined with precision in the case imagined by Sir John Herschel, (all the planets in one straight line on the same side of the sun). But in such an inquiry we can neglect minutiae and need consider only the four primary planets, while we may regard the distance of any one of these planets from the center of gravity of the whole system as appreciably equal to the distance from the sun's center the difference of these distances being exceedingly small compared with either.

"Calling the sun's mass 1, and the distance of the center of gravity of the sun from the center x, we find, taking moments about the common center of gravity,

Sun's moment=Jupiter's+Saturn's+Uranus'+Neptune's, or

$$1\times x=\frac{482,700,000}{1,048}+\frac{885,000,000}{3,500}+\frac{1,779,830,000}{22,600}+\frac{2,788,500,000}{19,380}$$

i. e., x=460,000+253,000+79,000+145,000=937,000 in round numbers.

"Showing that the center of gravity of the whole solar system would, in the case supposed, lie more than half a million, more exactly, 505,000 (937,000—432,000) miles from the sun's surface."—*Proctor's Old and New Astronomy, p. 301.*

Again he says:

"(759): The orbit of the sun is complex in shape since it is compounded of the circling motions which would severally result from the action of the different planets. We may neglect the movements due to the four inner planets as insignificant in range, though of course in any exact computation they would have to be taken into account. Taking the four giant planets separately, we find from what is shown in the note to Art. 713 that the sun would describe (1) if Jupiter alone were considered a circle (slightly eccentric but not appreciably elliptical) round the center of gravity of Jupiter's mass and his own, once in Jupiter's period, the radius of the orbit being about 460,000 miles; (2) considering Saturn alone, a circle round the center of gravity of Saturn's mass and his own, once in Saturn's period, the radius of the orbit being 253,000 miles; (3) considering Uranus alone, a circle 79,000 miles in radius, round the center of gravity of Uranus' mass and his own, once in Uranus' period; and (4) considering only Neptune a circle 145,000 miles in radius round the common center of gravity of his own mass and Neptune's in Neptune's period. The actual motion of the sun would be that compounded of these four circling motions with their different periods, and such smaller motions as would result from the disturbing actions of the several smaller planets, satellites, asteroids, etc. The curve would be exceedingly complicated even if we considered only the motions due to the four giant planets. Here we need only note that the greatest range of the sun from the common center of gravity of the solar system can never exceed 940,000 miles, and very seldom approaches that amount."—*Proctor Old and New Astronomy, p. 323.*

"The total mass of the solar system may be taken as follows:

"(Earth's mass=1.)

Sun	332,262
Jupiter	317
Saturn	95
Neptune	17.4
Uranus	14.6
Earth	1.0
Venus	.8
Mars	.11
Mercury	.06
Satellites	.20
Minor planets	.25
Total	332,708.42."

—*Appendix, Note A, "Visible Universe" Gore*

Taking the latest accepted figures I find the mass effect of the eight great planets upon the sun to be as follows:

(Sun's mass equals 1.)

Jupiter's mass $=\frac{1}{1,047.35}$, mean distance 483,000,000 miles; divided by mass plus one $=$ 461,010 miles, which is the distance by which the center of gravity of the sun is displaced by the attraction of Jupiter.

Saturn's mass $=\frac{1}{3,502}$, mean distance 886,000,000; displacement=252,926 miles.

Uranus' mass $=\frac{1}{22,760}$, mean distance 1,781,900,000; displacement=78,287 miles.

Neptune's mass $=\frac{1}{19,500}$, mean distance 2,791,600,000; displacement= 143,151 miles.

Total displacement of center of gravity of sun (or rather distance of center of gravity of solar system from sun's center) by four great planets when all pulling in one line on the same side equals 935,374 miles.

Earth's mass $=\frac{1}{332,000}$, mean distance 92,900,000 miles; displacement= 280 miles.

Venus' mass $=\frac{1}{384,460}$, mean distance 67,200,000 miles; displacement= 174 miles.

Mars' mass $=\frac{1}{3,093,000}$, mean distance 141,500,000; displacement=45 miles.

Mercury's mass $=\frac{1}{6,990,500}$, mean distance 36,000,000; displacement=5 miles.

Total displacement effected by last four planets, under same conditions, 504 miles.

Therefore the mere pulling influence of the last four planets may be neglected as comparatively insignificant.

But any calculations based upon the ancient idea of the sun's immobility will be misleading. For the purposes of this first chapter I will assume that the sun is moving through space from heliocentric longitude 90° towards 270° at the speed of eleven miles a second; that being the most conservative speed now stated by astronomers and it is entirely sufficient for this exposition. The question of the actual velocity of the sun in its journey to its apex is involved in the next chapter.

All references herein to longitudes are to *heliocentric* longitude unless otherwise expressed.

I have calculated and used tables of the heliocentric mean longitude, to the nearest degree, of the eight planets on the first day of January for each year back to 1000 B. C. In such an investigation as this greater accuracy is not necessary.

Upon these tables I have based the computations in Tables I, II, III, appendix and the other tables in the body of this pamphlet.

A few instances will illustrate their use.

On January 1st, 1843, the heliocentric longitude of the four great planets was as follows: Jupiter, 307°; Saturn, 288°; Uranus, 4°; Neptune, 321°.

The resultant of their combined attraction was to drive the sun out of its course 870,000 miles from the center of gravity of the solar system which was that distance away from the center of the sun in the direction 308° longitude. This distance is the vector and it is the hypothenuse of a triangle of which one side is the perpendicular distance of the sun—east or west—from the line formed by the progress of the center of gravity of the system; the other side shows the distance at which the center of the sun is ahead—plus—or behind—minus—of center of gravity of the system, measured in the path of the center of gravity and being plus or minus as respects the solar apex. The two sides of the triangle give the ordinates of the sun's position relative to the center of gravity of the solar system and to the solar apex.

For the years 1844 to 1851 the positions of the planets and their effect upon the sun are given by Table II. Let us assume the fact that the center of gravity of the solar system (hereinafter called the center of gravity) follows a right line in the journey towards the solar apex and that the direction of that line is from 90° towards 270°; then, by plotting the ordinates of the sun's position and the position of the center of gravity of the system and joining them with the vector lines, for the years 1843 to 1851, we will get the path pursued by the sun during those years. We can assume arbitrarily for the yearly advance of the sun one inch per year and plot the ordinates on a scale of 200,000 miles=1 inch.

From such a plat we find that the sun's path through space for those years is a curved line on the west side—towards heliocentric longitude 180°—of the straight line described by the advance of the center of gravity of the system during that period; and that, about the date 1850.2, the curved line, formed by the advance of the center of the sun, crossed the straight line; formed by the center of gravity of the system; and, at the end of the year 1850 the sun's center had reached a point about 40,000 miles to the east side of the straight line. That during this period the sun was in the rear of the center of gravity until about the middle of the year 1845 after which it was in advance of the center of gravity. Figure 1 shows a plotting for the last 18 years.

Plotting, from the figures in Table II, the path of the sun's center and of the center of gravity of the system for each year—from 1480 to 1910, with the vector lines connecting, we will observe the following facts:

The path of the sun through space, following the general direction to its apex from 90° to 270°, is a serpentine curve alternating on either side of a straight line produced through space by the progress of the center of gravity of the solar system. This curved path is caused by the varying positions of the planets and by the combined attraction of their mass and motion.

The extreme distance of the center of the sun from the line of the center of gravity is reached when the planets are in closest conjunction and may at times amount to 934,000 miles.

The sun, relative to the direction of its motion is alternately in advance of or in the rear of the center of gravity of the system, sometimes to the extent of 934,000 miles and sometimes but a very few miles. The sun is therefore retarded or assisted, in its progress through space by the position of the planets and the direction and amount of their combined attraction.

These alternating conditions are periodical and the periods recur and are caused as follows: Jupiter is in conjunction with Saturn every 19.855 years; with Uranus every 13.81 years; with Neptune every 12.78 years. All four are nearly in conjunction as follows: Jupiter with Neptune every 38.345 years; Jupiter with Saturn every 39.71 years; Jupiter with Uranus every 41.43 years. So that about every 40 years or thereabouts after or before a perfect conjunction these planets would again be nearly in line.

But they make a more perfect conjunction as follows: Jupiter with Saturn every 178.695 years; Jupiter with Neptune every 178.944 years; Jupiter with Uranus every 179.553 years.

Assuming the planets to have started even from zero, by combination of these periods we ought to get a series of periodical conjunctions more or less perfect every 40, 138, 178, and 218 years and so on.

The four great planets were in very close conjunction about September 26, 1306. That is the closest position on line with the sun in which I have found them as far back as 1000 B. C. On September 26, 1306 their longitudes were Jupiter, 231°; Saturn, 217°; Uranus, 227°; Neptune 231°. The resultant of their attraction was in the direction 226.5° and the distance of the center of gravity of the system from the sun's center was 934,000 miles.

In the early part of 1307—my tables call for April 30th—all of the eight great planets were gathered nearly on line with the sun between longitudes 213° and 258°. (My calculations are based upon mean longitude. No account is taken of the exact positions of Mercury or Mars. Their pull value is negligible so it does not matter where they were exactly on that date.)

We can use, therefore, January 1, 1307 as a zero epoch whence we can reckon, backward or forward, for recurrence of epochs of conjunction, of the four great planets.

But it is impossible to completely describe, in words merely, the results to be obtained from the figures in Table II of the appendix. They should be plotted by the reader—such a plat is too bulky to print. I used 12 yards of cross section paper ten inches wide to plat from 1480 to 1910. I assumed an arbitrary scale of 1 inch per year to represent the advance of the sun to its apex at any speed, and a scale of one inch equal to 200,000 miles to plot

the positions of the centers of gravity, the center of the sun, and the length and direction of the vector line joining those centers. As the advance of the sun is not represented to scale the positions of the center of gravity will lead to confusion unless that fact is kept in mind. With this plat we obtain an exaggerated curve for the path of the sun's center similar to the exaggerated curve of an engineer's line of levels where two scales are used one—horizontal—and arbitrary—the other—vertical—and true.

I will assume that the reader has made such a plat or that Figure 1 answers as an illustration. He will see that, when the vector line coincides with the path of the center of the gravity, the sun, or the resultant of the planets attractions, is ahead or astern with regard to the journey to the solar apex. The exact moment is determined when the curved line of the sun's center crosses the straight line generated by the center of gravity. If the sun is ahead of the resultant, or center of gravity, then the sun will be exerting its motive power to pull the planets along its path and to overcome their resistance. If the center of gravity is ahead of the sun then the planets are exerting their motive power to pull the sun along its path. This results naturally from the operation of the Newtonian law that attractions are equal and opposite and the general motion of the solar system is always in one direction namely towards the apex.

During the period of a great year, namely every 178 years, or from the perfect conjunction of the planets to another like epoch, we will find several minor periods marked by the condition that, for a short period of years, the sun is towing the planets; and, during the next short period, the planets are towing the sun. These shorter periods vary one from another as the planets are concentrated or dispersed from time to time exerting more or less force in opposition to the sun. Thus we get what we may call seasons in this great year period—applying old terms to new uses.

The beginning and ending of each period which is marked by sun or planets being in tow, is, of course, determined by the date when the vector line from the sun's center to the center of gravity is at right angles to the path of the center of gravity.

Therefore, in the determination of these periods, the beginning, the ending and the maximum of each period are subjects of precise calculation and may be graphically shown by the plat.

I will assume for the present, giving reasons later on, that the period during which the sun is in the lead pulling the planets along its path is a period of sun-spot maxima; and that the period during which the planets are in the lead—that is when the center of gravity is in the lead—is a period of sun-spot minimum.

The plat made therefrom and the Table II show that epochs of perfect conjunction occurred in 1486, 1665 and 1844; and that, in 1486.35, 1663.65 and 1841.1 the sun was crossing the line of the center of gravity towards

the west namely towards heliocentric longitude 180° ; in each instance being in tow of the planets astern. These dates may then be taken as epochs, or definite points of commencement of epochs, of similar solar and planetary conditions. Arranging the ordinates of the sun's motion as in Table III, we can examine the parallel conditions during these three periods, two of which are completed; these periods covering our precise records of solar activity.

From Table III and the plat it will be seen that the ordinates of the sun's path, as it crosses the path of the center of gravity, from side to side conform very nearly in every detail. Yet there is that difference, between similar conditions, which would be expected from the more or less perfect conjunctions of the planets and from the fact that such conjunctions never consecutively occur in the same part of the heavens. As we have seen, at the head of the three columns of Table III, the sun was crossing to the west of the line. In 1489 the middle ordinate of the western curve was 540,000; in 1667 it was 715,000 miles; in 1845 it was 820,000. In 1493.24 the sun was crossing the line to the east side, or towards the first point in Aries and it was so crossing in 1671.95 and in 1850.3, each time commencing, as we will see, a sun-spot maximum period. It began a new maximum period in 1504.07, 1681.9 and 1859.6; the intervals between these two sets of periods being 10.83 years, 9.95 years and 9.3 years respectively. So that while there was complete parallelism between these great year seasons there were also systematic differences.

We are now ready to examine these tables in connection with observed and tabulated events connected with the sun principally its sun-spot maxima and minima.

In the tabulation of sun-spot periods following the accepted table of sun-spot maxima and minima was taken from Miss Clerke's History of Astronomy, Appendix.

I have paralleled the minima column with a column giving the dates constituting the periods during which the planets—the center of gravity—was in the lead of the sun and pulling it along its path. This column is also paralleled with a column of dates when the center of gravity of the system was directly in the lead; the sun being astern like a ship being towed into harbor. Alongside that column is another showing the intervals in years between the latter epochs. This last column shows the same irregularity which characterizes the generally accepted intervals between periods of sun-spot maxima and minima and in this case it constitutes the strongest item of evidence of the fact that this table, *derived in this manner entirely from data absolutely free from a doubtful assumption or theory*, is in fact a table which demonstrates the relation of cause and effect between solar agitation and planetary position and motion. The same system of tabulation follows for the sun-spot maxima.

TABLE OF SUN-SPOT MINIMA.

Sun-spot Minima (from Agnes Clerke's History of Astronomy)		Period during which the planets were pulling the sun, i.e., center of gravity was in the lead			Dates when the sun was astern of the center of gravity	Intervals between years
Year	Intervals between years	Year		Year		
1610.8		1601	to	1608.1	1605.20	
1619	8.2	1614	"	1618.2	1616.3	11.05
1634	15	1625	"	1632.5	1630.35	14.10
1645	11	1635	"	1643.7	1639.9	9.55
1655	10	1649	"	1655.5	1652.65	12.75
1666	11	1659.4	"	1668.4	1663.65	11
1679.5	13.5	1672.2	"	1677.8	1673.55	9.9
1689.5	10	1685	"	1691.3	1687.9	14.35
1698 1698~~.9~~	9.4	1696	"	1701.8	1698.05	10.15
1712	13.1	1710	"	1713.3	1711.76	13.71
1723.5	11.5	1720	"	1726.5	1723.28	11.52
1734	10.5	1733	"	1736.5	1734.15	10.87
1745	11	1744	"	1750.4	1747.8	13.65
1755.2	10.2	1755	"	1761	1758.1	10.3
1766.5	11.3					
		1769	"	1772.5	1771.9	13.8
1775.5	9					
1784.7	9.2	1779	"	1786	1783.1	11.2
1798.3	13.6	1792	"	1796.5	1794.65	11.55
1810.6	12.3	1803	"	1811	1807.8	13.15
1823.3	12.7	1812	"	1821	1817.25	9.45
1833.9	10.6	1827	"	1833	1830.2	12.95
1843.5	9.6	1837	"	1845.8	1841.1	10.95
1856	12.5	1850.8	"	1855.3	1851.6	10.5
1867.2	11.2	1863	"	1869	1865.95	14.35
1878.9	11.7	1874	"	1879.5	1876.15	10.2
1890.2	11.3	1887.1	"	1891.4	1890.2	14.05
1901.9	11.7	1897.5	"	1904.8	1901.05	10.85

TABLE OF SUN-SPOT MAXIMA.

Sun-spot Maxima (from Agnes Clerke's History of Astronomy)		Period during which the sun was pulling the planets, i. e., sun was in the lead of center of gravity			Dates when the center of gravity was astern of the sun	Intervals between years
Year	Intervals between years	Year		Year		
1615.5		1608.1	to	1614	1610.8	
1626	11.5	1618.2	"	1625	1621.3	10.5
1639.5	13.5	1632.5	"	1635	1632.7	11.4
1649	9.5	1643.7	"	1649	1646.45	13.75
1660	11	1655.5	"	1659.4	1657.05	10.6
1675	15	1668.4	"	1672.2	1671.95	14.9
1685	10	1677.8	"	1685	1681.9	9.95
1693	8	1691.3	"	1696	1694.1	12.2
1705.5	12.5	1701.8	"	1710	1706.3	12.2
1718.2	12.7	1713.3	"	1720	1716.2	9.9
1727.5	9.3	1726.5	"	1733	1730.2	14
1738.7	11.2	1736.5	"	1744	1740.5	10.3
1750.3	11.6	1750.4	"	1755	1752.8	12.3
1761.5	11.2	1761	"	1769	1765.05	12.97
1769.7	8.2					
		1772.5	"	1779	1774.8	9.75
1778.4	8.7					
1788.1	9.7	1786	"	1792	1788.6	13.8
1804.2	16.1	1796.5	"	1803	1799.05	10.45
1816.4	12.2	1811	"	1812	1811.65	12.6
1829.9	7.3	1821	"	1827	1824.7	13.05
1837.2	12.6	1833	"	1837	1835.5	10.8
1848.1	10.9	1845.8	"	1850.8	1850.3	14.8
1860.1	12	1855.3	"	1863	1859.6	9.3
1870.6	10.5	1869	"	1874	1872	12.4
1884	14.4	1879.5	"	1887.1	1883.8	11.8
1894	10	1891.4	"	1897.5	1894.05	10.25
		1904.8	"		1907.86	13.81

While examining these tables of sun-spots maxima and minima it must not be forgotten that the original maker of the tables given by Miss Clerke—Dr. Rudolf Wolf—did not claim precision for the dates.

Professor Young says:

"The observations both of the sun-spots and of the magnetic elements near the close of the eighteenth century are so meager and unsatisfactory that the evidence as to the precise time of maxima and minima is very incomplete. It is even doubtful, as has been said before, whether there should not be recognized an additional sun-spot maximum in 1795, over and above those enumerated by Wolf."—*The Sun, p. 155.*

Proctor gives the same table of sun-spot maxima and minima from 1705 to 1883.8 in which the "possible error in years" is given as follows: For 1705 it is two years; for 1717.5 and 1727.5 one year; for 1738.5 one and a half years, and for 1750 one year. He says:

(821): "Professor Wolf, in forming his estimate of the mean period of spot variation, endeavored to judge, from the imperfect record of sun-spots during the eighteenth century, at what times spots were most or least numerous. *This part of the evidence cannot be regarded as trustworthy. Even if accepted as such, it can be interpreted in more ways than one,* insomuch that epochs regarded by Wolf as marked by minor maxima or mimima—the crests or hollows of mere wavelets of disturbance riding on the main waves—have by others been regarded as indicating true maxima or minima."

After giving the table Proctor proceeds. (823): "Taking this table as it stands we have fifteen intervals from the maximum of 1705.0 to that of 1883.8, a range of 178.8 years, whence the mean spot period, 11.92 years, would be deduced. The minima give fourteen intervals between 1712 and 1878.5, a range of 166.5 years, whence we get the mean spot period, 11.89. Wolf estimate was 11.11 years. It has been suggested that a small maximum may have occurred in 1797, which has here been overlooked; and a period of 10.45 years has been inferred. All that can be regarded as certainly established is that the oscillation of spot frequency is irregular, the interval between maxima having ranged from 7¾ to 15½ years, and the interval betweeen minima from 9 years to 13¾ years. *No average period even can at present be regarded as established;* and as for the idea that we may find in regular minor oscillations some way of making the main oscillations appear regular (as being regularly modified), we may regard all attempts in that direction as not merely hopeless, but unscientific."—*Proctor Old and New Astronomy, 348-9.*

Upon these and many other like authorities I do not think it would be profitable to discuss the many reasons why the tables I give, based on planetary motion, could be reconciled as to their differences with Dr. Wolf's tables.

The methods of observing sun spots during the last forty years have been totally changed. Schwab and Wolf merely counted the spots and the days of observation. Wolf relied upon his search in the records of the past as to the number of spots seen by astronomers who chanced to record their observations.

With the materials available to him he worked wonders and it seems to me that had he persisted in his theory of planetary influences, and *had taken into account the right planets*, he would have crowned his work with a perfect theory fortified by laborious induction.

The modern system of observing spots takes into account their area and the repetition of the same spots also their correct position on the sun and their time relations to terrestial phenomena, besides preserving photographs of the spots.

The correspondence between the epochs of maxima and minima and the tables I have given, from 1878.9 to date, is remarkable, considering that the movements of the planets cannot be jockeyed nor the figures derivable therefrom "coaxed", to use Miss Clerke's term, and that the basis of each set of tables are totally different in their elements.

But the greatest strain on sun or planets by their respective loads may not always correspond to the moment when that load is directly astern; so that some variation may ultimately be made in the tables on that account.

Returning now to the plat of the positions of the sun and center of gravity of the system it will be soon observed therefrom that marked periods occur at lesser, but irregular, intervals, besides those before given, on theory, from the calculated positions of the conjunction of the planets, viz., 40, 138, 178 and 218 years.

Owing to the slower or faster motion of some one of the planets in arriving at the conjunction goal, the 178 year period changes epoch. A more perfect conjunction occurs at a different date. I find the great year epochs change according to the following table, which gives merely the date and vector of the center of gravity of the system. Each column, it will be seen, consists of dates a great year's distance apart, but it will be noticed that the conjunction waxes and wanes.

TABLE OF EPOCHS OF CONJUNCTION OF PLANETS.

B.C.		B.C.		B.C.	
917	**925,000**	981			
738	**910,000**	802		839	
560	**885,000**	623		660	
380	**890,000**	444		481	
202	**855,000**	265		303	
23	800,000	**83**	**905,000**	123	
A.D.		A.D.		A.D.	
153		**93**	**870,000**	54	
332		**272**	**895,000**	233	810,000
512		**451**	**910,000**	412	840,000
690		**630**	**920,000**	590	860,000
870		**809**	**920,000**	770	870,000
1048		**988**	**930,000**	**948**	**920,000**
1227		**1167**	**910,000**	**1127**	**930,000**
1406		1346	890,000	**1306**	**934,000**
1586		1525	865,000	**1486**	**920,000**
1764		1704	835,000	**1665**	**905,000**
		1883	810,000	**1844**	**880,000**

The complete data for these epochs is given in Table I, Appendix.

From each of these dates a new set of subordinate periods will arise, originating the great rollers and wavelets, about which Miss Clerke and Proctor have written. This table, with the plat and Table III of the appendix, will show how high and in what order these figurative waves are raised. They will almost enable us to measure the great waves of convulsed gases which sweep around the sun and dash into the heavens their spray for hundreds of thousands of miles.

We have outlined in figures a condition from which the reader can see that at times the sun is towing its whole convoy of cruising planets through the boundless ocean of space, now with a very long tow line, again with a very short one; if we can conceive that the vector length between the sun's center and the center of gravity of the system is the tow line. Sometimes the sun tows a heavy load, sometimes a light load, as measured by the displacement of the sun, which is effected from time to time by the united or separated attraction of the planets. This displacement varies from 10,000 to 934,000 miles.

At other times the planets become tow boats for the colossal battleship, towing him in like manner as he tows them.

So far we have dealt merely with the coincidence of the dates of these alternating results of solar and planetary motion with the dates determined from observations for the solar disturbances—the maxima and minima of

sun spots. We have now to consider the physical consequences to the sun and planets of the alternating conditions of their progress towards the apex.

An illustration of the nature of this varying condition is hinted at by Sir John Herschel's comparison, heretofore quoted, which was criticised, as we have seen by Proctor.

Most of my readers are familiar with hammer-throwing as a field sport. The "hammer" is usually a ball of lead, 16 pounds weight, fastened to a light rod of iron as a long handle. Conceive the sun *"leaning a little back as it were to resist their force"*—as Herschel said. Conceive a hammer-thrower trying to maintain a vertical and rigid position while the hammer is swiftly circling about him preparatory to the throw. He would be speedily thrown on his face. The hammer-thrower *must* lean back from the direction of the ball until his pull equals the pull of the ball. But let us figure him swinging at once four hammers of varying size, which, as they circle about him, separate at varying angles and, now and then, join on one line and exert all their pull in one direction. The hammer-thrower will be in alternating conditions of stress; now he is pulled one way by the united force, again the pull comes from four directions at once, each hammer's pull neutralizing the pull of another. Again let us imagine him moving rapidly—say on roller skates, and, thus moving, swinging his hammers, and we will have a varying condition of strain in all directions, now urging him forward, again sideways, or even arresting his progress, as the motion of the hammers in their circuits may cause.

Such is the condition of the sun. As it glides through space to its apex it is urged sideways, backwards or forwards with an energy immeasurably greater than our conceptions of horsepower or kilowatts can express. It is subject to a constant and variable physical stress from without that must act upon its mobile mass as a shaking grate acts upon a boiler fire.

Sir R. S. Ball says:

"There are no absolutely rigid bodies known in nature, for the hardest mineral or toughest steel must yield to some extent when large forces are applied to it, and as the bodies in the system are not mere points or particles of inconsiderable dimensions they will experience stresses something like those to which our earth is subjected in that action of the moon and sun which produces the tides. In consequence of the influences of each body on the rest, there will be certain relative changes in the parts of each body; there will be as it were tidal movements in their liquid parts, and even in their solid substance."—*The Earth's Beginning, p. 219; also Winchell's World Life, 2d Ed. 1883, pp. 222, et seq.*

The strength of the gravitational force binding the earth to the sun has been likened to that of innumerable steel telegraph wires set as thickly in the earth as blades of grass. Let us imagine that such bonds of force—invisible—envelop like a net Jupiter and the sun and control in their

meshes every particle of the solid and gaseous materials of those bodies, the strands between forming rigid cables uniting the bodies. When by their motions—Jupiter circling about the sun, the sun rushing towards its apex—those bodies change their relative positions one to the other, there will result a drawing of these nets and a compression of the enclosed spheres changing their forms to pear-shaped spheroids with their smaller ends pointed towards each other; a tide of matter will be literally squeezed out on that side of each globe nearest to the other and will course around each sphere as each body rotates upon its axis.

So if all four of the great planets are so bound, pulling upon their net-like bonds a bulging of the mass of the sun and a squeezing of its material towards the opposing planets must result. At the moment when all four are in one line on one side of the sun compression will be exerted to the uttermost upon the elastic gases of the sun as if it were in the socket of a ball and socket joint when the screw was being tightened. At these times motion is compelled in the sun's mass towards the planets; and, upon those parts of the sun which are denuded of such tide-forming material, outbreaks of the submerged matter and guess—relieved temporarily of super-incumbent weight—will occur as a result of their expansion, which may be so violent as to constitute an explosion.

Now reverse the order of the procession, putting the planets in the lead moving towards the apex, then the pull upon the sun's mass will, to that extent, be relaxed. Then the compressed gases of the sun will expand and will be redistributed by gravitation about the sun, and it will regain its speroidal form. Thus the sun will have alternating periods of compression and expansion of varying degrees of intensity proportional to the amount and direction of the attractive forces of the planets and the degree of unity or diversity in their action.

Now let us see how far observation tends to support these suggestions. We need merely mention the fact that Helmholtz propounded the generally accepted theory of the gravitational shrinkage of the sun as the cause of its heat; and that Sir Wm. Herschel, Arago and others have traced an annual variability in the quantity of heat by the variable crops and their prices, corresponding to sun-spots periods.

In 1884 Dr. J. Helfiker published a pamphlet in which he discussed the variability of the solar diameter, using 3,468 transits of the sun observed during 22 years at the Neuchatel Observatory and found that such changes in the diameter of the sun bore a relation to the period of the sun-spots; that is to say, that the greatest diameter coincided with the minimum of the period of sun-spots and vice versa.—*Observatory for Sept. 1884, p. 263; T. Hilfiker, Premiere etude sur les observations du diametre du Soliel. Bulletin de la Societe des Sciences Naturelle, Neuchatel Tome. XIV.*

Professor Charles Lane Poor, in June, 1905, published an article on the "Figure of the Sun", giving photographic evidence "that the ratio between the polar and equatorial radii of the sun is variable, and that the period of this variability is the same as the sun-spot period." He says: "The sun appears to be a vibrating body whose equatorial diameter on the average exceeds the polar diameter. At times, however, the polar diameter becomes equal to and even greater than the equatorial—the sun passing from an oblate to a prolate spheroid. In this variable figure may be the explanation of the anomalies in the motions of Mercury, Venus and Mars."—*Astrophysical Journal, Vol. 22, p. 113.*

"Measurements made by the same person, however, and with the same instruments, but at different times, sometimes differ enough to raise a suspicion that the diameter is slightly variable, which would be nothing surprising, considering the nature of the solar surface.—*Young, "Sun," p. 45, Ed. 1881.*

In the facts and events suggested by this chapter we have a sufficient cause for the shrinkage and expansion of the sun which fits all of the observations and theories of solar activity, both as to the time of their occurrence and as to the variable intensity of their action.

We may summarize as follows:

There is a disturbance of the sun's mass and motion by the planets which is sufficient at times to drive the whole mass of the sun aside from its path to the extent of twice the diameter of the moon's orbit. Such a force, acting upon a body of elastic gas, must raise what—for want of a better name—we must call a tide or tides of great height. The flow of these tides relieves the pressure upon portions of the sun, allowing submerged gases—too heavy to be ordinarily exposed—to manifest their existence by ebullition and explosion, giving rise to phenomena only periodically displayed.

The tables show that the energy of the planets is maintained almost constantly upon the sun's motion. It is very frequently sufficient to drive the sun aside from its path 600,000 miles; still more frequently 200,000 miles; the exceptions to the latter force being as infrequent as to the exertion of the greatest force—viz., that exceeding 600,000 miles.

It is therefore probable that this merely physical disturbance of the sun's mass—this constant and variable raking of the solar fires—gives rise to all of the effects known as spots, prominences, coronas, magnetic storms and other phenomena of solar activity.

EARTHQUAKES WHICH ARE PROBABLY CAUSED BY SOLAR AND PLANETARY ACTION.

The theory of the generation of the moon, propounded by Professor G. H. Darwin—see his work on "Tides"—outlines the first case of solar action producing an earthquake, for which we have his mathematical authority. As such it antedates all geological records displayed to us in faults, fissures, mountains and volcanoes. Prof. Wm. H. Pickering, in an article published in Harper's Magazine for June, 1907, briefly outlines this theory of the moon's generation.

Not all earthquakes are the result of solar action. An earthquake is a shaking of the earth's crust. A shock produced by the explosion of a giant powder factory will give the same effects as a slight earthquake. Some earthquakes are directly traceable to explosions of steam and some to explosions of other gases.

Some are indeterminate, perhaps partly terrestrial and partly solar in origin.

Prof. G. H. Darwin says:

"Earthquakes are probably due to unequal shrinkage of the planet in cooling, and each shock would tend to bring the strata into their position of rest; thus the earth's surface would avail itself of the opportunity afforded by earthquakes of acquiring its proper shape."—*Darwin's Tides, p. 300-1.*

Both Darwin and Sir R. S. Ball unite substantially in the following opinion:

"The attractions of the moon and sun must certainly act not only on the sea, but also on the solid earth; and, since the earth is not perfectly rigid or stiff, they must produce *an alternating change* in its shape. Even if the earth is now so stiff that the changes in its shape escape detection through their minuteness, yet such changes of shape must exist."—*Darwin's Tides, p. 3; Ball, The Earth's Beginning, pp. 163, 164, 168, 176.*

At certain periods of the progress of the solar system during the past 28 centuries violent earthquakes have occurred. Our information is for the most part confined to those occurring in Europe or around the Mediterranean Sea. After the beginning of the 16th century, A. D., America was included in the catalogue. Such early Chinese and Japanese records as are available strengthen the inferences to be drawn herein from the European records.

As to the very early records it may be safely asserted that only those records of earthquakes of great and widespread intensity have been handed down, because early civilization and reliable history centers about the Mediterranean Sea, which has always been earthquake territory. Conse-

quently a commonplace, ordinary quake would pass unnoticed, and, in most instances, the early records manifestly deal with great earthquakes only.

The few instances of Chinese and Japanese ancient records also deal with world-shaking events.

The epochs when all the great planets were in conjunction, as shown by Table I, appendix, have been historically marked by world-shaking quakes in almost every instance, as will be seen from an examination of Mallett's "Earthquake Catalogue" R. and F. W. Mallet 1858.

The dates when the sun is crossing the line of the center of gravity, as shown by Table III, either, while in tow of, or while being towed by the planets, are also the dates of many great earthquakes.

The periods during which the sun makes its widest departures, East or West, of the path of the center of gravity, namely in excess of 500,000 miles, are also periods when many of our great quakes happen.

The same effects must be produced upon each planet by the alternating conditions of progress, as are visibly produced upon the sun when it varies from maxima to minima of violent disturbance, that is, great commotion and movement in its fluid or gaseous, or even solid materials, and shrinkage or expansion around the equatorial zone.

Whether this shrinkage or expansion can be measured depends on the condition of the planet. A movement of the crust of the earth, horizontally or vertically, for 10 or 20 feet will not represent, as to the whole globe, much of a shrinkage or expansion, but it may result in the ruin of a city or a state. To the extent that the earth is mobile and plastic enough to respond to the stress put upon it during seasons of great stress, to that extent should its crust yield to the shrinkage or expansion of its interior. Even cold steel and iron can be made to yield and change form under cold pressure in the mechanic arts, not alone in minute, but in great masses. The idea that the earth is rigid or stiff enough, therefore, to resist the almost immeasurable stresses put upon it by the solar system can have no foundation. If great cataclysms in the past have rent it through and through, establishing fissures deeply and extensively across the earth it would be reasonable to expect that, when the strain was again felt, the earth would again yield practically along the same lines, reopening the same fissures. Observation in mines and elsewhere shows such repeated breaks. Periodical recurrence of earthquakes along the same line, which are not accompanied by evidence of explosive force, or of falling, and which affect, during short intervals, the whole sphere along a great circle, and which occur uniformly with certain conditions of the progress of the solar system, point to a causal relation of the two conditions.

The visible condition of the moon is that it is a wreck of moon quake activities, seamed with fissures, honeycombed with volcanoes and wrinkled with mountain chains, the product of shrinkage.

The visible condition of the sun is an almost "continuous performance" of sun quake, varying in intensity, as we have seen.

The condition of the other planets seems to be the same so far as observation can determine.

Referring to Tables I and II, the reader will see that the year 1804 was a conjunction epoch, the four great planets being nearly in line, Saturn lagging back.

August 5th, 1803, Schröter found Saturn not perfectly spheroidal in figure. In April and May, 1805, Sir Wm. Herschel, after most careful observations to exclude all instrumental or other errors, found that Saturn "resembles a parallelogram, one side whereof is parallel to the equatorial, the other to the polar diameter, with the four corners rounded off so as to leave both the equatorial and the polar regions flatter than they would be in a regular spheroidal figure." He renewed these observations in 1806 with the same result. But he found that in 1807 a change had taken place in the aspect of the planet. In 1818 Kitchener saw the same figure. The changing form of the planet has been often noticed.

Proctor concludes: "We seem almost compelled, therefore, to accept the conclusion that the planet Saturn is subject to the influence of forces which either upheave portions of its surface from time to time, or cause vast masses of cloud to rise to an enormous height above the mean level of Saturn's cloud envelope. * * * which—to be discernable from our distant standpoint—would imply the expansion and contraction of whole zones of Saturn's surface through 4,000 or 5,000 miles at least."—*Proctors Familiar Science Studies, p. 61; Proctor's Other Worlds Than Ours, Saturn; Proctor's Astronomical Essays, 101; Arago Pop. Ast., Vol. 2, p. 599.*

Jupiter also exhibits these changes of form.

Proctor says:

"We have seen, however, that evidence is not wanting to prove that Jupiter is really liable to occasional changes of figure, though not to such an extent as to change the general aspect of the planet."—*Other Worlds Than Ours, pp. 151, 157, 173; Familiar Science Studies, pp. 60, 75; Arago Pop. Ast., Vol. 2, p. 521.*

The "canals" of Mars may be, in part at least, immense fissures. There is no reason apparent why any planet should differ from another in being subject to such planet quakes.

Another form of force is manifested by the sun as a product of its commotions, different from the merely mechanical energy of its moving mass. The electrical effects upon the earth, which have been traced to the sun as a cause, are as closely connected with its variable condition as are its spots. Such effects as "magnetic storms" have been connected with particular meridians and latitudes of the sun. A "storm" having been observed to originate when a particular spot appeared, a repetition of the storm has

been observed when the synodical rotation of that part of the sun had again brought it to bear upon the earth. But as the rotation speed of the sun varies the repetition of the phenomena will occur at a longer or shorter interval. The sidereal rotation of the sun at the equator requires 25 days $4\frac{1}{2}$ hours, while at North latitude 50° and South latitude 45° it requires 27 days $10\frac{3}{4}$ hours. We must add 2 days to the sidereal time in order to get the synodical time of rotation, so that some latitudes of the sun require the same length of time to complete a revolution, *respecting the earth,* as does the moon. Thus, for those latitudes of the sun, the moon becomes a clock with which to time the rotation of those portions of the sun; and, as such portions are very active, we may have here the reason for the popular belief in the moon as a cause of many terrestrial phenomena which in fact have their origin in the sun, earthquakes among the number.

Perrey's catalogues of earthquakes and his efforts to connect the phases of the moon therewith may have great value when examined from the view of the sun being the cause.

In an article published in Harper's Magazine for May, 1905, "Magnetic Storms and the Sun", Professor Maunder says that he noticed that when certain great sun-spots reached the center of the sun's disc a great magnetic storm broke out on the earth, accompanied in one instance by a most remarkable aurora. He says that he "noticed four disturbances toward the end of the year 1886 and four in the middle of the following year, which succeeded each other at almost equal intervals of time; the intervals being, on the average, about twenty-seven days eight hours—just the interval which it takes, on the average, for a sun-spot to pass from the center of the sun's disc round to that center a second time."

From this article it would seem as if great electrical guns were mounted upon the sun which now and then, loaded by its energy and, getting our range as they swing round, give us a shot to emphasize our mortality. These electrical discharges may prove to be of many kinds and from different latitudes of the sun.

I refer again to the long list of earthquakes extending over a great period of time catalogued by Mallet, which were accompanied by auroras, loud detonations, electrical storms and other electrical phenomena of a most extraordinary character. It is also to be remarked that extraordinary alternations of heat and cold, wind and rain, storms of great violence, mark earthquake years, as evidenced by that catalogue and by the years 1906 and 1907.

It is also to be noticed that the time within which magnetic or electrical forces reach the earth after starting from the sun is in doubt, it appearing that some forms of this force are instantaneous, quicker than light, while other forms are very slow comparatively. Ricco and Arrenhius calculate

45 hours as the time required for electrical force to reach the earth from the sun.—*Sci. Am. Supp. July 15th, 1905, p. 20,698.*

But, in the article already quoted, Prof. Maunder makes the suggestion that when the magnetic or electrical streams proceeding from the sun happen to intersect the earth they cause a release of energy in the electrical forces of the earth "as a spark may set free the disruptive forces in a store of gunpowder. The solar action will be indeed the cause of the storm, but it will be so, not as supplying the forces put forth in it, but as giving them the opportunity to reveal themselves."

A PRELIMINARY CHAPTER ON SOLAR AND PLANETARY MOTION.

The object of this chapter is to briefly state some facts, in a new relation, which tend to show that the sun's motion towards the solar apex has a critical speed which it must maintain in order to furnish planetary paths conformable to observation, and that such speed exceeds that given by some authorities and need not be as great as allowed by others. The most recent authorities are very conservative, but as their observations govern their results it cannot be said that any bias exists in favor of a great or a slow speed. They give a speed of about 12 miles a second. Miss Clerke, however, exhibited the natural bias of an elderly lady in saying: "We are not whirled in the train of such a stellar projectile as 1830 Groombridge."

There is another purpose in this chapter, which is to secure attention to the true motion of the solar system, which is certainly quite different from that set forth by Copernicus or Kepler, but which, nevertheless, still conforms to the mathematical relations stated by Kepler and Newton when proper allowance is made for the solar and planetary motion towards the solar apex.

In 1890 Miss Clerke summed up the conclusions of astronomers as to the direction of the sun's motion by placing the apex in R. A. 273° 21′, north declination 27° 19′; and gave the speed at 14½ miles per second—*History of Astronomy, pp. 324, 325, 3rd Ed.*

Again she said:

"But when from the *direction* we attempt to pass to the *amount* of solar motion, the case becomes widely different. Flagrant contradictions abound. *Estimates of velocity range at large between five and 150 miles a second;* the criteria of truth are at the mercy of individual judgment. The cause of these discrepancies lies in the uncertainty still prevailing as to the distances of the stars. * * *

"It is nevertheless tolerably certain that the solar pace has nothing headlong about it. We are not whirled in the train of such a stellar projectile as 1830 Groombridge or Zeta Toucani. Our condition were it so would be betrayed by unmistakable tokens. Everything, on the contrary, suggests the inference that our sun is among the sedately moving stars."—*System of the Stars, p. 326, Agnes M. Clerke, Oct., 1890.*

Again she says:

"We do not know the plane of the sun's orbit—only the direction of one line in it, and that line, pointing towards the constellation Hercules, makes an angle of about 60° with the sun's equator. Thus, the solar movements of rotation and translation *would seem to be unrelated one to the other;*

and the same remark applies to the planetary revolutions conducted, on the whole, along levels of space differing very little from that of the great globe's axial movement. Our whole system is then driven obliquely upward by a power which, taking no apparent account of its domestic economy owned doubtless an origin totally disconnected from that of gyrations given, through it influence, the helicoidal shape illustrated in Fig. 48." (Here follows a figure showing the sun's way directed upward at an angle of 55° from an ellipse to represent perhaps the principal plane of the solar system, and about it the path of the earth consisting of a long arc followed by a small loop similar to figure 3 herein.)—*Clerke, System of the Stars, p. 330.*

The speed of 14.5 miles per second equals 460 million miles per annum.

Sir John Herschel rates the speed of the sun at 154 million miles per annum, or nearly 5 miles a second, very much the slowest of any speed assigned.—*Outlines of Astronomy, Art. 858.*

Prof. Newcomb, in "The Stars", published in 1902, cites many authorities giving different directions and speeds and sums up as follows:

"From all these results it would seem that the most likely apex of the solar motion is towards a point in Right Ascension 280°, Declination 30° North. This point is situated in the constellation Lyra about 4° from the first magnitude star, Vega.—*The Stars, Newcomb, p. 91.*

At page 93 he gives a speed of 19 kilometers per second, or 11.8 miles, or 372 million miles per year.

Maedler estimated the sun's motion towards the apex at 30 miles per second, or 946,728,000 miles yearly.—*Clerke's Hist. of Ast., 49.*

And Raneken estimated it at 9.79 times the radii of the earth's orbit.—*Phil. Soc. Wash., Vol. XI, pp. 143, 171.*

Raneken's estimate is over 907 million miles yearly—about 28 miles a second.

Miss Clerke does not cite the authorities who assign a velocity up to 150 miles a second.

As a result we find professional astronomers estimating the sun's motion through space at a speed of from five to 150 miles a second, with a direction that varies in longitude from 260° to 289°, and in declination from +14° to +53°. Professor W. W. Campbell, the latest cited, places the declination at +20°.

In ordinary terms the sun's path is in a plane inclined to the ecliptic and to the principal plane of the solar system and the angle of inclination is in dispute to the extent of 40°.

The speed and the angle of inclination of the sun's path to the principal plane of the solar system are of most consequence in this chapter.

By reference to many books it will be seen that the sun's path through space is depicted like that of a rocket rising into the heavens from a field bounded by an ellipse to represent the principal plane of the solar system,

while the earth is shown winding upwards and around the sun's path in an ascending spiral, like a ball under the feet of a performer in a circus.

See Miss Clerke's "System of the Stars", p. 330.

Variety is given to this by Flammarion; he shows the same spiral, but descending, "falling" literally, he says. (Pop. Ast., p. 52.)

Still more elaborate is an illustration in Gillet and Rolfe's Astronomy, p. 369, showing the spiral paths of all the planets with earth and moon prominently wiggling their compound way "up dem golden stairs."

According to these illustrations, the solar system follows an inclined cylindrical path upwards at an angle of about 55° from the plane of revolution of the solar system, in which plane the horizontal trace of the spiral path of each planet forms a closed ellipse.

This, of course, is very foreign to the Copernican system. But the stationary sun called for by that system is now replaced by a body which, as we have seen, is said to move at a velocity somewhere between 5 and 150 miles per second, and it is felt that something must be said to reconcile the two repugnant ideas—namely revolutions of the planets, in closed ellipses with a swiftly moving body around which such revolutions take place.

Miss Clerke says: "We do not know the plane of the sun's orbit—only the direction of one line in it." That was an oversight, because the fact that the sun makes an irregular cycloidal revolution about the center of gravity of the system was no doubt well known to her. As we have already seen this orbit may extend at times 934,000 miles or more to one side of that center. So we have a plane nearly two million miles across, with a line in that plane formed by the motion of the center of gravity. Therefore, we have a plane nearly 2 million miles wide and infinitely long, extending in the general direction from 90° to 270° heliocentric longitude, in which the sun moves. The plane of the sun's motion by virtue of the sun's mass is approximately the principal plane of the solar system.—*Ball's Earth's Beginning, pp. 208, 210.*

But all the motions of the great planets take place within two planes very closely parallel to the principal plane *according to observation,* whether such motion is in closed ellipses, epicycles, spirals, serpentine or other curved paths.

The proposition involved is whether planetary motion through space with the sun, *and as viewed from the stars,* is cylindrical and spiral or whether it is essentially confined to a plane (using that term here to signify a flat space confined within two planes) and the planetary motions are in open or closed curves.

Is the principal plane of the solar system like the floor of an elevator moving up or down a shaft?

With reference to the walls of the shaft, does the astronomer see the bricks of the shaft moving up or down in lines perpendicular to the floor

of the elevator, or, in lines oblique to that floor? If he sees the stars moving in lines very oblique to the principal plane of the system then the spiral paths of the planets—if they are spiral—will be very flat and may be fairly represented by their horizontal trace in the plane of the solar system.

But under any of the modern theories of this motion—as to direction and speed—it is evident that the path of a planet cannot be a closed ellipse unless the solar apex lies in a line perpendicular to the principal plane of the solar system.

The motions of the moon have been more closely studied than those of any other body. The papers and books of Prof. G. H. Darwin have presented them again in a new way. In his papers and books on tidal forces he traces mathematically the history of the earth and moon "until the moon nearly touches the earth, and the two go round each other like a single solid body in about three to five hours."—*Tides, p. 278.* * * * "It is by methods of rigorous argument that the moon is traced back to the initial unstable condition when she revolved close to the earth. But the argument here breaks down, and calculation is incompetent to tell us what occurred before, and how she attained that unstable mode of motion.—*Tides, p. 281.*

* * * * * * * * * * * *

"We have grounds for conjecturing that the moon is composed of fragments of the primitive planet which we now call the earth, which detached themselves when the planet spun very swiftly, and afterwards became consolidated."—*Same, p. 282.*

He then mathematically traces the history of earth and moon forward, saying:

"The moon must then always face the same part of the earth's surface, and the two bodies must move *as though they were united with a bar.* The outcome of the lunar tidal friction will therefore be that the moon and the earth go round as though locked together in a period of fifty-five of our present days, with the day and the month of identical length."—*p. 276.*

* * * * * * * * * * * *

"The series of changes then proceed until the two periods come again to an identity, when we have the earth and the moon *as they were at the beginning,* revolving in the same period, with the moon always facing the same side of the earth. But in her final condition the moon will be a long way off the earth, instead of being quite close to it."—*p. 280.*

"When there is only one day in the month, the earth and the moon go round at the same rate, so that the moon always looks at the same side of the earth, and so far as concerns the motion *they might be fastened together by a rigid bar.*"—*p. 277.*

In this argument the professor does not indicate *that the present motion of the moon* is other than that most usually indicated in the books, namely a motion of the moon around the earth in a closed ellipse. Nor does he indi-

cate when the present mode of motion of the moon began, nor when it will end. But he does emphatically say that when the moon was nearly touching the earth the two went round each other like a dumb-bell pivoted in the handle and that in the end they will go round in the same way, except that the handle of the dumb-bell will be very much longer.

But the moon does not move about the earth in that manner *now*.

Flammarion described the present mode of motion of the moon and claims to be the first to correctly describe that motion.

He said:

"A rather curious fact generally forgotten is that this sinuous curve is so elongated that it scarcely differs from that which the earth annually describes round the sun; and instead of being (as it is always drawn in astronomical treatises) convex to the sun, at the epoch of every new moon, it is always concave to the sun! I have represented it exactly (Fig. 42) on the scale of 1 millimetre to 100,000 leagues. In this figure the arc of the terestrial orbit is drawn with an opening of the compass of 37 centimetres for 37 millions."—1 (In a note he says):

"*This true form of the lunar orbit was drawn for the first time in 1876 in the first edition of our Terres du Ciel.*"—*Flammarion Pop. Ast., p. 108.*

Proctor was particularly careful to illustrate and describe the path of the moon about the earth correctly. He, indeed, classes the moon as a planet which travels in the same orbit as the earth.—*Old and New Astronomy, p. 492.*

Perhaps he was so careful because he had scolded the "paradoxists" so vigorously in his "Myths and Marvels of Astronomy," p. 274, while at the same time admitting that the fault lay with the text writers. He did not effect a reform in that respect. Holden's Astronomy, published in 1899, by Henry Holt, pp. 216 and 217, repeats the old error by description and illustration.

But the books do not give the figures which show simply the real path and elements of the moon's motion. As that is the foundation upon which I wish to build I will briefly outline the figures.

The geocentric longitude and radial distances of the moon are facts of observation. Let us assume that the earth is motionless for 27⅓ days, and that the moon starts a "revolution" of the earth at longitude 90° while in perigee there. Calculating the position of the moon for each two days we will get columns 1 to 9 of Table IV, appendix. By plotting the figures of cols. 5, 6 and 9 we get points in a closed ellipse.

Now let us give the earth its motion and assume it to travel in a straight line towards longitude 270°, and, adding that motion for each two days to the moon's ordinates, which lie in the major axis of the ellipse, we get columns 10 and 11 of the same table. Plotting columns 5, 6 and 11 of the table we get the actual path of the moon about the earth, namely a serpen-

tine curve formed of two arcs, one on each side of the earth's path, the chord of the first arc being about 97 times longer than its middle ordinate. This path of the moon is like that of Fig. 5, illustrating a theoretical path for Mercury.

The real path of the moon is not a closed ellipse, yet it is derived from the theory of a closed elliptical orbit.

But Professor Darwin's description of the original motion of the earth and moon, immediately after their separation, calls for an epicycle curve; that is, if the planets move forward with the sun *as if fastened with a bar*, the earth not rotating. If the bar were removed we can easily conceive them moving as they do now, no matter at what distance they were separated. But the original mode of motion of the moon and the present mode constitute a problem in planetary evolution which we may well leave with Professor Darwin.

Does Mercury "revolve" around the sun or does it circulate about it as the moon now circulates about the earth?

Is the path of Mercury, as seen from the stars, a closed ellipse, or an epicycle which completely encircles the sun, or an epicycle which does not encircle the sun, or is it an epicycle of any sort?

The mathematical theory of the motion of Mercury, as of all the other planets, deals with them as if they moved around a stationary body, the sun, in a closed ellipse. And as the observations of the motions of the planet in their orbits can be reconciled with these mathematical theories we must conclude *that the sun does not move* or else that these theories of closed elliptical orbits can be reconciled with the sun's motion in the same way as we did the motion of the moon in a serpentine path about the earth.

The constants of observation as to the heliocentric longitude and radial distance of Mercury from the sun and the plane of its motion are facts.

So long as the sun was conceived to be an island in space around which the planetary ships coasted the course of Mercury was settled as a closed ellipse.

Let us continue that assumption during one "revolution" of Mercury and let us start Mercury at 90° heliocentric longitude, and from that point tabulate its courses for every five days, except the last course, and we will get columns 1 to 9 of Table V of the appendix. Plotting the figures in columns 6, 7 and 9 we get points in a closed ellipse.

Now let us assume that the sun moves at a uniform speed in the direction from 90° to 270°. By adding that motion to the ordinates of Mercury, which lie in the path of the sun's motion, for each five days, we can examine the different orbits or paths which Mercury would pursue based upon the different rates of speed assigned to the sun.

If we begin at the slowest speed, that given by Sir John Herschel, 5 miles a second, we will get columns 10 and 11 of Table V. By plotting

these figures, with cols. 5 and 6, yield a true epicycle which encircles the sun, and by repeating the path for 264 days we see the planet making loops about the sun and crossing its own path on the 6th course when making its 21st course. See Figure 2.

But such an orbit is declared to be impossible by one astronomer.—*Comstock Text Book of Astronomy, 59-60.*

If we take the next highest rate of speed for the sun, between 11.8 and 18.5 miles a second—say 16 miles as a mean—and tabulate that speed we get columns 12 and 13 of Table V. Plotting these figures, namely columns 5, 6, 12 and 13 of Table V. (see Figure 3), we get a large curve for the first 9 courses on the west side of the sun's path, then a small loop for the remainder of the planet's journey, the loop beginning when the planet crosses the line of the sun's path. On the 13th course you will notice that the planet makes on the 13th course but about one-fourth of the distance that it made on the first course. This loop in Mercury's path—"to port"—is like that famous loop made by Admiral Schley in the "Brooklyn" at the sea battle of Santiago, about which there was so much controversy.

But about this loop in the path of Mercury, upon a supposed speed of the sun at 16 miles a second, or 11.8 miles, or 14.5 miles, or 18.5 miles, all of which have been assigned, *there should be no controversy.* If the sun proceeds to its "apex" at any such rate then Mercury makes such a loop, larger or smaller, as the sun's speed varies, between those figures, and that real loop should be observable when the earth is on the line of the sun's way or near the line, at 90° or 270° heliocentric longitudes. Such occasions often happen. Mercury is then at its greatest elongation. *Apparent* loops in Mercury's path are observed soon after Mercury has commenced this real loop and before it is finished, and such *apparent* loops are very large and open, more so than that of any planet except that of Venus. —*Proctor's Old and New Astronomy, p. 158.*

Proctor says: "In the case of Mercury, it is the large inclination of the planet's path to the eliptic which causes the loop to undergo remarkable changes of shape."

So that no difficulty ought to exist in observing a real loop if any such was made. But as none has been observed it must be assumed that none is so made *and it follows that the sun does not move at any such rate of speed.*

Tabulating the speed of the sun at 33 miles a second, we get columns 14 and 15 of Table V. (Remember the speed assigned to the sun by Rancken was 28 miles a second and by Mädler 30 miles a second.)

Plotting the path upon this new speed, see Figure 4, we get a peculiar figure. The first 13 courses give a large curve on the west side of the sun crossing the line on the 9th course. At the beginning of the 14th course Mercury spins around, on its heel as it were, and takes up a new

Fig. 4.
Mercury's Path
Sun going 33 miles a second

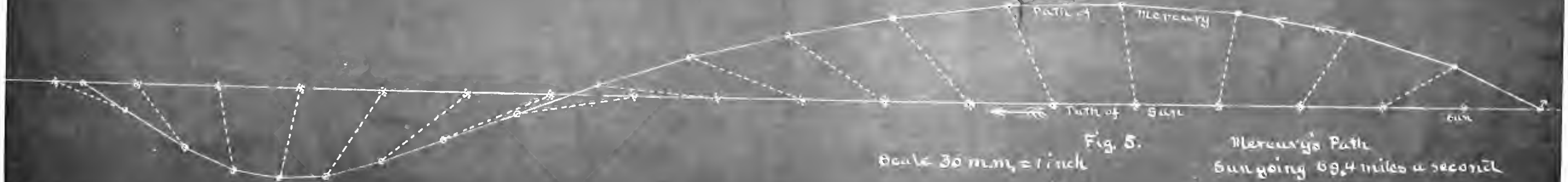

Fig. 5.
Scale 30 m.m. = 1 inch
Mercury's Path
Sun going 69.4 miles a second

course, almost retrograde to the 13th course, and from that point starts a new curve like that of the previous courses. *At this speed of 33 miles Mercury ceases to form a loop in its path.* It is not conceivable, however, that the planet actually performs such a maneuver.

Assuming that the sun moves 6,000,000 miles a day, 69.4 miles a second, we get columns 16 and 17 of Table V, which yield, by plotting, see Figure 5, a path about the sun like that of the moon about the earth, except that the chords of the arcs are not nearly so long compared with the middle ordinate.

The closed elliptical orbit of Mercury, when combined with the sun's motion at a certain speed, gives the same results as we obtain for the moon.

Therefore no difficulty is encountered with the elliptical mathematical theory when combined with the proper—shall we say "critical"?—speed of the sun. Moreover, at that speed, 69.4 miles per second, all of the planets will be found pursuing the same sort of a path about the sun when the tabling of their "orbits" is made upon the same basis.

We have seen that some claim is made that the sun moves 150 miles a second, which is over twice as great a speed as is necessary to make the paths of the planets serpentine curves.

There is nothing about the speed of 69.4 miles a second which is improbable.

That speed would require 2689 years to cover one light year's distance.

Nor is it true that all celestial bodies move in elliptical orbits. The sun is not *known* to so move. Nor are many of the stars, some of which have very great proper motion, with immense velocity.—*Newcomb's Stars, p. 158.*

Maxwell Hall and others have endeavored to assign an elliptical orbit and position of central sun with the modest period of 20 million years for one revolution. The sun's path in that orbit would be a straight line—humanly speaking.

Having, therefore, precedent in the motions of the sun and moon, we can say that not all of the members of the solar system move in a closed ellipse, or epicycle, and that there is ground for dispute that any of the planets so move.

There are some conclusions to be drawn from this method of examination. The most important is that, as the sun's plane of motion is the principal plane of the solar system, and such plane determines the planes of the planets' movements, then there are certain rates of speed of the sun which cannot be reconciled with the known movements of the planets.

The speed of the sun also determines the *actual* speed of the planets. For instance, the earth is ordinarily said to move in its orbit at 18.5 miles a second. But that is based upon the assumption that the orbit is a closed ellipse around an anchored sun. When we add the motion of the sun

we increase to an extent, dependent upon the rate of speed of the sun, the velocity of the earth, which it is therefore certain very much exceeds 18.5 miles a second.

Upon the actual speed of the sun and its planets depends the estimates of force exerted by one upon the other during their separated or combined actions as discussed in chapter one.

Upon the actual position of the principal plane of the solar system, and the speed in that plane, as well as the direction therein of the moving bodies, depends all those estimates of energy exerted by the sun upon the planets and by the planets upon the sun.

APPENDIX.

TABLE I.

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year B. C.	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
917	62°	38°	58°	59°	55°	925,000	+760,000	W 535,000
738	94°	66°	105°	90°	87°	910,000	+910,000	W 45,000
560	97°	81°	148°	119°	100°	885,000	+870,000	E 155,000
380	160°	130°	199°	152°	154°	890,000	+390,000	E 800,000
202	196°	172°	289°	210°	166.5°	855,000	+205,000	E 830,000
83	53°	110°	15°	70°	75°	905,000	+870,000	W 230,000
Year, A. D.								
93	116°	149°	67°	103°	119°	870,000	+760,000	E 420,000
272	148°	176°	114°	134°	151°	895,000	+440,000	E 780,000
451	181°	202°	160°	165°	183°	910,000	— 40,000	E 910,000
630	213°	229°	206°	195°	213°	920,000	— 55,000	E 770,000
809	246°	256°	254°	225°	247°	920,000	—840,000	E 375,000
948	144°	154°	130°	168°	149°	920,000	+500,000	E 790,000
988	279°	283°	301°	256°	280°	930,000	—915,000	W 150,000
1127	177°	180°	176°	199°	181°	930,000	— 20,000	E 930,000
1167	311°	309°	348°	286°	309°	910,000	—705,000	W 575,000
1306	231°	217°	227°	231°	226.5°	934,000	—700,000	E 625,000
1486	272°	246°	275°	263°	263.5°	925,000	—920,000	E 95,000
1665	304°	274°	322°	293°	295.5°	905,000	—820,000	W 40,000
1804	202°	172°	197°	236°	199°	880,000	—280,000	E 835,000
1844	335°	298°	1°	323°	327.5°	880,000	—465,000	W 750,000

TABLE II.

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
A. D. 1480	90°	173°	249°	250°	150°	435,000	+280,000	E 330,000
1481	121°	185°	254°	252°	164°	580,000	+155,000	E 550,000
1482	151°	197°	258°	254°	186°	700,000	— 30,000	E 700,000
1483	181°	209°	262°	257°	206°	805,000	—350,000	E 725,000
1484	212°	222°	267°	259°	226°	890,000	—635,000	E 620,000
1485	242°	234°	271°	261°	245°	925,000	—840,000	E 395,000
1486	272°	246°	275°	263°	263°	925,000	—920,000	E 95,000
1487	303°	258°	280°	265°	283°	880,000	—860,000	W 190,000
1488	333°	270°	284°	268°	302°	810,000	—690,000	W 430,000
1489	3°	283°	288°	270°	320°	700,000	—445,000	W 540,000
1490	34°	295°	292°	272°	340°	555,000	—190,000	W 520,000
1491	64°	307°	297°	274°	358°	400,000	— 15,000	W 400,000
1492	94°	319°	301°	276°	19°	225,000	+ 75,000	W 210,000
1493	125°	332°	305°	278°	61°	50,000	+ 45,000	W 25,000
1494	155°	344°	310°	281°	224°	120,000	— 80,000	E 85,000
1495	185°	356°	314°	283°	256°	290,000	—260,000	E 120,000
1496	216°	8°	318°	285°	267°	435,000	—430,000	E 30,000
1497	246°	21°	323°	287°	286°	550,000	—530,000	W 145,000
1498	277°	33°	327°	289°	307°	630,000	—510,000	W 375,000
1499	307°	45°	331°	292°	327°	690,000	—380,000	W 575,000
1500	337°	58°	335°	294°	348.5°	700,000	—140,000	W 690,000
1501	8°	70°	339°	295°	15.5°	690,000	+130,000	W 680,000
1502	38°	82°	343°	297°	35.5°	660,000	+380,000	W 535,000
1503	68°	94°	347°	299°	60°	610,000	+625,000	W 300,000
1504	99°	106°	352°	302°	88.5°	560,000	+560,000	W 15,000

TABLE II (*Continued*).

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1505	129°	118°	356°	304°	119°	515,000	+455,000	E 250,000
1506	159°	130°	0°	306°	151.5°	490,000	+235,000	E 425,000
1507	190°	143°	5°	308°	184°	485,000	— 35,000	E 480,000
1508	220°	155°	9°	310°	214°	500,000	—280,000	E 410,000
1509	250	167°	13°	312°	244°	520,000	—465,000	E 230,000
1510	281°	179°	18°	314°	271°	530,000	—530,000	W 10,000
1511	311°	191°	22°	316°	296.5°	520,000	—465,000	W 230,000
1512	341°	204°	26°	319°	320°	505,000	—320,000	W 390,000
1513	12°	216°	30°	321°	345.5°	440,000	—105,000	W 425,000
1514	42°	228°	35°	323°	12.5°	355,000	+ 75,000	W 345,000
1515	72°	240°	39°	326°	45°	270,000	+190,000	W 190,000
1516	103°	253°	43°	328°	90°	190,000	+185,000	0 00
1517	133°	265°	47°	330°	157°	175,000	+ 80,000	E 165,000
1518	164°	277°	52°	332°	209°	270,000	—125,000	E 235,000
1519	194°	290°	56°	334°	241°	390,000	—340,000	E 180,000
1520	224°	301°	60°	336°	266°	525,000	—520,000	E 35,000
1521	255°	314°	65°	339°	295.5°	640,000	—600,000	W 215,000
1522	285°	326°	69°	341°	311.5°	745,000	—560,000	W 490,000
1523	315°	338°	73°	343°	331.5°	815,000	—390,000	W 710,000
1524	346°	350°	77°	345°	352.5°	865,000	—115,000	W 850,000
1525	16°	3°	82°	347°	12.5°	865,000	+180,000	W 845,000
1526	46°	15°	86°	350°	32°	845,000	+450,000	W 715,000
1527	77°	27°	90°	352°	53.5°	780,000	+665,000	W 465,000
1528	107°	40°	95°	354°	74°	695,000	+625,000	W 190,000
1529	137°	52°	99°	356°	95°	585,000	+580,000	E 60,000
1530	168°	64°	103°	358°	119°	450,000	+395,000	E 215,000
1531	198°	76°	107°	0°	145°	315,000	+180,000	E 255,000
1532	228°	88°	112°	2°	181°	185,000	0 000	E 190,000
1533	259°	101°	116°	4°	264°	135,000	—130,000	E 35,000
1534	289°	113°	120°	7°	320°	190,000	—120,000	W 150,000
1535	319°	125°	125°	9°	358°	300,000	— 10,000	W 300,000
1536	350°	137°	129°	11°	26°	400,000	+170,000	W 355,000
1537	20°	149°	133°	13°	51.5°	480,000	+370,000	W 300,000
1538	51°	162°	137°	15°	76.5°	535,000	+520,000	W 130,000
1539	81°	174	142°	17°	100.5°	585,000	+570,000	E 105,000
1540	111°	186°	146°	20°	124.5°	610,000	+500,000	E 345,000
1541	142°	198°	150°	22°	150°	620,000	+310,000	E 540,000

TABLE II (*Continued*).

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1542	172°	211°	155°	24°	178°	615,000	+ 20,000	E 615,000
1543	202°	223°	159°	26°	202°	615,000	—240,000	E 565,000
1544	233°	235°	163°	28°	231.5°	610,000	—480,000	E 375,000
1545	263°	247°	167°	31°	261°	610,000	—600,000	E 110,000
1546	293°	259°	172°	33°	285.5°	605,000	—585,000	W 160,000
1547	324°	272°	176°	35°	313.5°	605,000	—440,000	W 420,000
1548	354°	284°	180°	37°	338.5°	595,000	—215,000	W 550,000
1549	24°	296°	185°	39°	4°	560,000	+ 35,000	W 560,000
1550	55°	308°	189°	41°	30°	515,000	+225,000	W 440,000
1551	85°	321°	193°	44°	56°	460,000	+380,000	W 260,000
1552	115°	333°	197°	46°	83°	380,000	+375,000	W 50,000
1553	146°	345°	202°	48°	114°	290,000	+265,000	E 120,000
1554	176°	357°	206°	50°	154°	215,000	+ 95,000	E 190,000
1555	206°	9°	210°	53°	214°	175,000	— 95,000	E 140,000
1556	237°	22°	215°	55°	270°	220,000	—220,000	0 000
1557	267°	34°	219°	57°	310°	345,000	—270,000	W 215,000
1558	298°	46°	223°	59°	337.5°	435,000	—165,000	W 400,000
1559	328°	58°	227°	61°	3.5°	540,000	+ 30,000	W 550,000
1560	358°	70°	232°	63°	26°	625,000	+275,000	W 560,000
1561	29°	83°	236°	66°	50°	690,000	+530,000	W 440,000
1562	59°	95°	240°	68°	72°	740,000	+640,000	W 230,000
1563	89°	107°	245°	70°	94°	765,000	+765,000	E 50,000
1564	120°	119°	249°	72°	116.5°	760,000	+680,000	E 340,000
1565	150°	131°	253°	74°	139°	730,000	+480,000	E 550,000
1566	180°	144°	257°	77°	163°	685,000	+205,000	E 655,000
1567	211°	156°	262°	79°	187°	620,000	— 75,000	E 610,000
1568	241°	168°	266°	81°	213.5°	540,000	—290,000	E 450,000
1569	271°	180°	270°	83°	241°	460,000	—405,000	E 220,000
1570	302°	192°	275°	85°	271°	390,000	—390,000	W 10,000
1571	332°	205°	279°	87°	307.5°	330,000	—220,000	W 200,000
1572	2°	217°	283°	90°	345°	290,000	— 75,000	W 275,000
1573	33°	229°	287°	92°	20°	290,000	+ 95,000	W 270,000
1574	63°	241°	292°	94°	43°	165,000	+110,000	W 120,000
1575	93°	254°	296°	96°	104°	295,000	+285,000	E 70,000
1576	124°	266°	300°	98°	143°	325,000	+190,000	E 265,000
1577	154°	278°	305°	101°	177°	370,000	+ 20,000	E 370,000
1578	184°	291°	309°	103°	208.5°	400,000	— 30,000	E 355,000

TABLE II *(Continued)*.

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1579	215°	302°	313°	105°	241°	420,000	—370,000	E 200,000
1580	245°	315°	317°	107°	270°	520,000	—520,000	0 000
1581	275°	327°	322°	109°	297°	570,000	—515,000	W 260,000
1582	306°	339°	326°	111°	323°	645,000	—390,000	W 510,000
1583	336°	351°	330°	114°	347.5°	690,000	—150,000	W 675,000
1584	6°	4°	335°	116°	12.5°	735,000	+160,000	W 715,000
1585	37°	16°	339°	118°	36°	750,000	+435,000	W 610,000
1586	67°	28°	343°	120°	57°	755,000	+630,000	W 410,000
1587	97°	41°	347°	122°	81°	720,000	+710,000	W 115,000
1588	128°	53°	352°	125°	101°	680,000	+670,000	E 130,000
1589	158°	65°	356°	127°	122.5°	605,000	+505,000	E 330,000
1590	188°	77°	0°	129°	144°	500,000	+290,000	E 410,000
1591	219°	89°	5°	131°	167.5°	375,000	+ 80,000	E 370,000
1592	249°	102°	9°	133°	197°	250,000	— 70,000	E 235,000
1593	279°	114°	13°	136°	239.5°	120,000	—105,000	E 55,000
1594	310°	126°	18°	138°	342°	120,000	— 40,000	W 115,000
1595	340°	138°	22°	140°	31°	245,000	+125,000	W 210,000
1596	11°	150°	26°	142°	60°	390,000	+325,000	W 195,000
1597	41°	163°	30°	144°	82°	495,000	+490,000	W 70,000
1598	72°	175°	35°	146°	105°	610,000	+585,000	E 160,000
1599	102°	187°	39°	149°	127°	675,000	+640,000	E 400,000
1600	132°	200°	43°	151°	150°	720,000	+370,000	E 620,000
1601	163°	212°	47°	153°	170°	740,000	+125,000	E 730,000
1602	193°	224°	52°	155°	193°	745,000	—170,000	E 725,000
1603	223°	236°	56°	157°	215°	695,000	—400,000	E 565,000
1604	254°	248°	60°	160°	239°	620,000	—535,000	E 315,000
1605	284°	260°	65°	162°	266°	565,000	—565,000	E 45,000
1606	314°	273°	69°	164°	294°	500,000	—455,000	W 200,000
1607	345°	285°	73°	166°	327.5°	465,000	—250,000	W 395,000
1608	15°	297°	77°	168°	360°	445,000	0 000,000	W 445,000
1609	45°	309°	82°	171°	33.5°	425,000	+235,000	W 350,000
1610	76°	322°	86°	173°	65°	430,000	+390,000	W 180,000
1611	106°	334°	90°	175°	96°	425,000	+420,000	E 45,000
1612	136°	346°	95°	177°	124°	420,000	+350,000	E 235,000
1613	167°	358°	99°	179°	153°	395,000	+175,000	E 350,000
1614	197°	10°	103°	181°	182°	355,000	— 10,000	E 350,000
1615	227°	23°	107°	184°	214°	305,000	—170,000	E 250,000

TABLE II *(Continued)*.

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1616	258°	35°	112°	186°	257°	230,000	—225,000	E 50,000
1617	288°	47°	116°	188°	287°	245,000	—200,000	W 140,000
1618	318°	59°	120°	190°	351°	395,000	— 45,000	W 290,000
1619	349°	72°	125°	192°	29.5°	380,000	+185,000	W 340,000
1620	19°	84°	129°	195°	57°	505,000	+425,000	W 270,000
1621	49°	96°	133°	197°	82.5°	625,000	+620,000	W 80,000
1622	80°	108°	137°	199°	104.5°	690,000	+670,000	E 170,000
1623	110°	120°	142°	201°	127°	815,000	+650,000	E 485,000
1624	140°	133°	146°	203°	147.5°	870,000	+470,000	E 730,000
1625	171°	145°	150°	205°	167.5°	890,000	+195,000	E 865,000
1626	201°	157°	155°	208°	186.5°	870,000	—100,000	E 855,000
1627	231°	169°	159°	210°	205°	825,000	—350,000	E 740,000
1628	262°	181°	163°	212°	224.5°	730,000	—505,000	E 520,000
1629	292°	194°	167°	214°	243.5°	620,000	—550,000	E 280,000
1630	322°	206°	172°	216°	262°	480,000	—475,000	E 30,000
1631	353°	218°	176°	219°	282°	305,000	—300,000	W 60,000
1632	23°	230°	180°	221°	303°	130,000	—110,000	W 70,000
1633	53°	243°	185°	223°	124.5°	45,000	+ 35,000	E 25,000
1634	84°	255°	189°	225°	254°	230,000	+100,000	E 200,000
1635	114°	267°	193°	227°	174°	275,000	+ 40,000	E 380,000
1636	144°	279°	197°	229°	193°	515,000	—115,000	E 500,000
1637	175°	291°	202°	232°	213°	635,000	—345,000	E 530,000
1638	205°	304°	206°	234°	232°	710,000	—560,000	E 435,000
1639	235°	315°	210°	236°	252°	750,000	—710,000	E 240,000
1640	266°	328°	215°	238°	277°	760,000	—760,000	W 30,000
1641	296°	340°	219°	240°	293°	740,000	—680,000	W 295,000
1642	326°	353°	223°	243°	316.5°	695,000	—480,000	W 500,000
1643	357°	5°	227°	245°	342°	625,000	—190,000	W 590,000
1644	27°	17°	232°	247°	8.5°	550,000	+ 80,000	W 545,000
1645	57°	29°	236°	249°	38.5°	485,000	+300,000	W 375,000
1646	88°	42°	240°	251°	74°	430,000	+415,000	W 110,000
1647	118°	54°	245°	253°	110°	425,000	+395,000	E 145,000
1648	148°	66°	249°	256°	144°	435,000	+250,000	E 355,000
1649	179°	78°	253°	258°	176°	460,000	+ 25,000	E 465,000
1650	209°	90°	257°	260°	204°	485,000	—195,000	E 445,000
1651	239°	103°	262°	262°	230°	500,000	—375,000	E 325,000
1652	270°	115°	266°	264°	255°	480,000	—460,000	E 130,000

TABLE II *(Continued)*.

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1653	300°	127°	270°	267°	280°	435,000	—430,000	W 70,000
1654	330°	139°	275°	269°	304°	365,000	—300,000	W 210,000
1655	1°	151°	279°	271°	340°	275,000	—100,000	W 250,000
1656	31°	164°	283°	273°	24.5°	195,000	+ 80,000	W 180,000
1657	61°	176°	287°	275°	86°	195,000	+200,000	W 10,000
1658	92°	188°	292°	277°	137.5°	305,000	+205,000	E 220,000
1659	122°	200°	296°	280°	168°	440,000	+ 90,000	E 425,000
1660	152°	213°	300°	282°	193°	570,000	—130,000	E 550,000
1661	183°	225°	305°	284°	216.5°	695,000	—415,000	E 550,000
1662	213°	237°	309°	286°	237°	795,000	—665,000	E 430,000
1663	343°	249°	313°	288°	257°	865,000	—840,000	E 200,000
1664	274°	261°	317°	291°	276.5°	900,000	—900,000	W 100,000
1665	304°	274°	322°	293°	295.5°	905,000	—820,000	W 400,000
1666	334°	286°	326°	295°	313.5°	865,000	—625,000	W 610,000
1667	5°	298°	330°	297°	334°	795,000	—390,000	W 715,000
1668	35°	310°	335°	299°	352°	685,000	— 95,000	W 680,000
1669	66°	323°	339°	302°	12°	555,000	+115,000	W 540,000
1670	96°	335°	343°	304°	31.5°	400,000	+210,000	W 335,000
1671	126°	347°	347°	306°	53°	225,000	+175,000	W 135,000
1672	157°	359°	352°	308°	96°	50,000	+ 50,000	E 5,000
1673	187°	11°	356°	310°	253°	135,000	—130,000	E 40,000
1674	218°	24°	0°	312°	287.5°	280,000	—275,000	W 35,000
1675	248°	36°	5°	314°	300°	430,000	—375,000	W 210,000
1676	279°	48°	9°	316°	319.5°	550,000	—355,000	W 420,000
1677	309°	60°	13°	319°	341°	620,000	—215,000	W 600,000
1678	339°	73°	18°	321°	1°	690,000	+ 15,000	W 690,000
1679	10°	85°	22°	323°	12°	725,000	+270,000	W 670,000
1680	40°	97°	26°	326°	44°	710,000	+475,000	W 490,000
1681	70°	109°	30°	328°	67°	695,000	+640,000	W 275,000
1682	101°	121°	35°	330°	92.5°	640,000	+640,000	E 30,000
1683	131°	134°	39°	332°	117°	580,000	+515,000	E 275,000
1684	161°	146°	43°	334°	148°	530,000	+280,000	E 450,000
1685	192°	158°	47°	336°	181°	500,000	— 5,000	E 495,000
1686	222°	170°	52°	339°	212°	480,000	—250,000	E 410,000
1687	252°	182°	56°	341°	243°	475,000	—425,000	E 215,000
1688	283°	195°	60°	343°	275°	480,000	—490,000	W 30,000
1689	313°	207°	65°	345°	302°	480,000	—410,000	W 250,000

TABLE II *(Continued)*.

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1690	343°	219°	69°	347°	329°	490,000	—250,000	W 420,000
1691	14°	231°	73°	350°	356.5°	460,000	— 30,000	W 450,000
1692	44°	244°	77°	352°	23°	415,000	+155,000	W 385,000
1693	74°	256°	82°	354°	51°	340,000	+265,000	W 210,000
1694	105°	268°	86°	356°	85°	265,000	+260,000	W 20,000
1695	135°	280°	90°	358°	130°	210,000	+160,000	E 135,000
1696	165°	292°	95°	0°	188°	215,000	— 30,000	E 215,000
1697	196°	305°	99°	2°	237°	300,000	—255,000	E 165,000
1698	226°	316°	103°	4°	268°	415,000	—410,000	E 10,000
1699	256°	329°	107°	7°	294°	425,000	—485,000	W 210,000
1700	287°	341°	112°	9°	319°	645,000	—425,000	W 485,000
1701	317°	354°	116°	11°	341°	730,000	—240,000	W 690,000
1702	347°	6°	120°	13°	1.5°	795,000	+ 25,000	W 790,000
1703	18°	18°	125°	15°	23°	830,000	+315,000	W 765,000
1704	48°	30°	129°	17°	42.5°	835,000	+565,000	W 615,000
1705	78°	43°	133°	20°	65°	830,000	+750,000	W 350,000
1706	109°	55°	137°	22°	85°	750,000	+745,000	W 70,000
1707	139°	67°	142°	24°	106°	660,000	+635,000	E 180,000
1708	169°	79°	146°	26°	126.5°	565,000	+445,000	E 340,000
1709	200°	91°	150°	28°	151.5°	435,000	+205,000	E 380,000
1710	230°	104°	155°	31°	180°	310,000	0 000,000	E 310,000
1711	260°	116°	159°	33°	219°	195,000	—120,000	E 145,000
1712	291°	128°	163°	35°	288°	135,000	—130,000	W 45,000
1713	321°	140°	167°	37°	352°	200,000	— 25,000	W 195,000
1714	351°	152°	172°	39°	30°	305,000	+150,000	W 260,000
1715	22°	165°	176°	41°	55°	355,000	+290,000	W 210,000
1716	52°	177°	180°	44°	84°	480,000	+470,000	W 45,000
1717	82°	189°	185°	46°	107°	535,000	+510,000	E 195,000
1718	113°	201°	189°	48°	133°	580,000	+420,000	E 400,000
1719	143°	214°	193°	50°	158.5°	610,000	+220,000	E 565,000
1720	174°	226°	197°	53°	184°	630,000	— 50,000	E 625,000
1721	204°	238°	202°	55°	210°	630,000	—310,000	E 550,000
1722	234°	250°	206°	57°	235°	635,000	—525,000	E 360,000
1723	265°	262°	210°	59°	263°	630,000	—625,000	E 80,000
1724	295°	275°	215°	61°	290°	630,000	—595,000	W 205,000
1725	325°	287°	219°	63°	315°	625,000	—440,000	W 440,000
1726	356°	299°	223°	66°	335°	620,000	—260,000	W 565,000

TABLE II *(Continued)*.

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1727	26°	311°	227°	68°	8°	575,000	+ 80,000	W 570,000
1728	56°	324°	232°	70°	33°	555,000	+300,000	W 465,000
1729	86°	336°	236°	72°	58°	500,000	+425,000	W 265,000
1730	117°	348°	240°	74°	86°	430,000	+430,000	W 30,000
1731	147°	0°	245°	77°	113°	345,000	+310,000	E 135,000
1732	177°	12°	249°	79°	148°	255,000	+135,000	E 215,000
1733	208°	25°	253°	81°	195°	185,000	— 50,000	E 180,000
1734	238°	37°	257°	83°	262°	185,000	—185,000	E 25,000
1735	268°	49°	262°	85°	304°	260,000	—210,000	W 150,000
1736	299°	61°	266°	87°	340°	365,000	—130,000	W 345,000
1737	329°	74°	270°	90°	8°	465,000	+ 60,000	W 460,000
1738	0°	86°	275°	92°	33°	570,000	+215,000	W 470,000
1739	30°	98°	279°	94°	56°	640,000	+540,000	W 360,000
1740	60°	110°	283°	96°	79°	715,000	+700,000	W 145,000
1741	91°	122°	287°	98°	101°	725,000	+710,000	E 140,000
1742	122°	135°	292°	101°	123.5°	760,000	+630,000	E 430,000
1743	152°	147°	296°	103°	145°	730,000	+420,000	E 615,000
1744	182°	159°	300°	105°	168°	705,000	+140,000	E 690,000
1745	213°	171°	305°	107°	192°	650,000	—140,000	E 630,000
1746	243°	183°	309°	109°	218°	575,000	—350,000	E 450,000
1747	273°	196°	313°	111°	245°	500,000	—455,000	E 220,000
1748	304°	208°	317°	114°	278°	420,000	—420,000	W 55,000
1749	334°	220°	322°	116°	308°	365,000	—285,000	W 220,000
1750	4°	232°	326°	118°	345°	315,000	— 85,000	W 305,000
1751	35°	245°	330°	120°	25°	295,000	+120,000	W 265,000
1752	65°	257°	335°	122°	65°	290,000	+255,000	W 125,000
1753	95°	269°	339°	125°	109°	295,000	+290,000	E 35,000
1754	126°	281°	343°	127°	138°	320,000	+210,000	E 235,000
1755	156°	293°	347°	129°	170°	340,000	+ 50,000	E 335,000
1756	186°	306°	352°	131°	205°	360,000	—155,000	E 325,000
1757	217°	317°	356°	133°	240°	405,000	—350,000	E 205,000
1758	247°	330°	0°	136°	272°	445,000	—445,000	W 15,000
1759	277°	342°	5°	138°	301°	510,000	—435,000	W 260,000
1760	308°	355°	9°	140°	330°	570,000	—280,000	W 500,000
1761	338°	7°	13°	142°	356°	645,000	— 35,000	W 640,000
1762	9°	19°	17°	144°	22°	705,000	+260,000	W 655,000
1763	39°	31°	22°	146°	45°	750,000	+525,000	W 535,000

TABLE II *(Continued).*

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1764	69°	44°	26°	149°	67°	770,000	+715,000	W 300,000
1765	100°	56°	30°	151°	89°	765,000	+765,000	W 15,000
1766	130°	68°	35°	153°	112°	725,000	+675,000	E 270,000
1767	160°	80°	39°	155°	131°	660,000	+505,000	E 430,000
1768	191°	92°	43°	157°	152°	600,000	+280,000	E 535,000
1769	221°	105°	47°	160°	173°	500,000	+ 55,000	E 490,000
1770	251°	117°	52°	162°	197°	365,000	—105,000	E 350,000
1771	282°	129°	56°	164°	223°	220,000	—150,000	160,000
1772	312°	141°	60°	166°	280°	85,000	— 80,000	W 15,000
1773	342°	154°	65°	168°	33°	135,000	+ 70,000	W 95,000
1774	13°	166°	69°	171°	71°	290,000	+270,000	W 110,000
1775	43°	178°	73°	173°	94°	430,000	+430,000	E 30,000
1776	73°	190°	77°	175°	114°	560,000	+510,000	E 235,000
1777	104°	202°	82°	177°	136°	645,000	+445,000	E 465,000
1778	134°	215°	86°	179°	159°	710,000	+260,000	E 665,000
1779	164°	227°	90°	181°	178°	755,000	+ 20,000	E 755,000
1780	195°	239°	95°	184°	199°	770,000	—250,000	E 725,000
1781	225°	251°	99°	186°	222°	745,000	—490,000	E 560,000
1782	255°	263°	103°	188°	244°	710,000	—640,000	E 310,000
1783	286°	276°	107°	190°	268°	645,000	—645,000	E 20,000
1784	316°	288°	112°	192°	295°	570,000	—520,000	W 240,000
1785	346°	300°	116°	195°	324°	495,000	—300,000	W 400,000
1786	17°	312°	120°	197°	357°	435,000	— 20,000	W 435,000
1787	48°	325°	124°	199°	34°	400,000	+220,000	W 330,000
1788	78°	337°	129°	201°	79°	390,000	+365,000	W 140,000
1789	108°	349°	133°	203°	112°	400,000	+390,000	E 85,000
1790	139°	1°	137°	205°	144°	410,000	+300,000	E 280,000
1791	169°	13°	142°	208°	162°	425,000	+130,000	E 400,000
1792	199°	25°	146°	210°	179°	420,000	+ 10,000	E 420,000
1793	230°	38°	150°	212°	219°	370,000	—235,000	E 290,000
1794	260°	50°	155°	214°	248°	330,000	—310,000	E 120,000
1795	290°	62°	159°	216°	284°	280,000	—270,000	W 65,000
1796	321°	73°	163°	219°	334°	270,000	—120,000	W 245,000
1797	351°	86°	167°	221°	18°	300,000	+ 90,000	W 290,000
1798	21°	99°	172°	223°	58°	385,000	+325,000	W 200,000
1799	51°	111°	176°	225°	88°	500,000	+500,000	W 15,000
1800	81°	123°	180°	227°	113°	615,000	+560,000	E 245,000

TABLE II *(Continued).*

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1801	111°	135°	185°	229°	136°	710,000	+490,000	E 515,000
1802	142°	147°	189°	232°	158°	795,000	+300,000	E 735,000
1803	172°	160°	193°	234°	179°	850,000	+ 20,000	E 850,000
1804	202°	172°	197°	236°	199°	880,000	—280,000	E 835,000
1805	234°	184°	202°	238°	218°	865,000	—540,000	E 680,000
1806	264°	196°	206°	240°	237°	820,000	—690,000	E 445,000
1807	294°	209°	210°	243°	257°	725,000	—705,000	E 180,000
1808	325°	221°	215°	245°	276°	605,000	—600,000	W 55,000
1809	355°	233°	219°	247°	293.5°	480,000	—440,000	W 195,000
1810	25°	245°	223°	249°	311°	310,000	—230,000	W 205,000
1811	56°	257°	227°	251°	329°	115,000	— 60,000	W 105,000
1812	86°	270°	232°	253°	171°	60,000	+ 10,000	E 60,000
1813	116°	282°	236°	256°	190°	230,000	— 40,000	E 225,000
1814	147°	294°	240°	258°	209°	395,000	—190,000	E 345,000
1815	177°	306°	245°	260°	228°	550,000	—400,000	E 375,000
1816	207°	319°	249°	262°	245°	650,000	—585,000	E 275,000
1817	238°	331°	253°	264°	265°	740,000	—740,000	E 60,000
1818	268°	343°	257°	267°	285°	780,000	—760,000	W 205,000
1819	298°	355°	262°	269°	305°	800,000	—660,000	W 455,000
1820	329°	7°	266°	271°	326°	770,000	—435,000	W 640,000
1821	359°	20°	270°	273°	348°	730,000	—145,000	W 715,000
1822	30°	32°	274°	275°	12°	650,000	+135,000	W,635,000
1823	60°	44°	279°	277°	38°	570,000	+355,000	W 440,000
1824	90°	56°	283°	280°	67°	490,000	+450,000	W 190,000
1825	121°	69°	287°	282°	102°	420,000	+405,000	E 90,000
1826	151°	81°	292°	284°	139°	390,000	+255,000	E 290,000
1827	181°	93°	296°	286°	176°	400,000	+ 30,000	E 400,000
1828	212°	105°	300°	288°	208°	425,000	—205,000	E 370,000
1829	242°	117°	304°	291°	240°	450,000	—385,000	E 225,000
1830	272°	130°	309°	293°	264°	470,000	—470,000	E 45,000
1831	303°	142°	313°	295°	291°	460,000	—425,000	W 160,000
1832	333°	154°	317°	297°	318°	420,000	—280,000	W 320,000
1833	3°	166°	322°	299°	346°	360,000	— 90,000	W 350,000
1834	34°	178°	326°	302°	18°	290,000	+ 90,000	W 275,000
1835	64°	191°	330°	304°	65°	225,000	+200,000	W 100,000
1836	94°	203°	334°	306°	116°	230,000	+200,000	E 100,000
1837	125°	215°	339°	308°	167°	290,000	+ 60,000	E 285,000

TABLE II *(Continued).*

Position of planets in heliocentric longitude on January 1st of each year: Year	Jup.	Sat.	Ura.	Nep.	Direction and distance from sun to center of gravity of system: Direction in heliocentric long.	Distance in miles	Sun's position relative to its apex and to center of gravity: On the course, miles	Off the course, miles
1838	155°	227°	343°	310°	197°	440,000	—120,000	E 420,000
1839	185°	240°	347°	312°	224°	560,000	—390,000	E 400,000
1840	216°	252°	352°	315°	247°	680,000	—620,000	E 270,000
1841	246°	264°	356°	317°	268°	770,000	—775,000	E 30,000
1842	272°	276°	354°	319°	288°	845,000	—805,000	W 270,000
1843	303°	287°	357°	321°	307.5°	880,000	—705,000	W 535,000
1844	335°	298°	1°	323°	327.5°	880,000	—465,000	W 750,000
1845	8°	309°	5°	326°	347.5°	840,000	—175,000	W 825,000
1846	42°	320°	9°	328°	7°	775,000	+ 95,000	W 770,000
1847	74°	332°	13°	330°	25°	680,000	+285,000	W 610,000
1848	105°	343°	17°	332°	45°	525,000	+375,000	W 370,000
1849	135°	355°	21°	334°	65°	390,000	+350,000	W 170,000
1850	163°	8°	25°	336°	86°	220,000	+215,000	W 15,000
1851	191°	20°	29°	339°	134°	50,000	+ 35,000	E 40,000
1852	218°	33°	33°	341°	285°	120,000	—120,000	W 30,000
1853	247°	46°	37°	343°	312°	285,000	—215,000	W 190,000
1854	277°	62°	41°	345°	334°	440,000	—200,000	W 390,000
1855	308°	74°	45°	347°	353°	565,000	— 65,000	W 560,000
1856	340°	88°	50°	350°	13°	640,000	+145,000	W 625,000
1857	13°	101°	54°	352°	34°	710,000	+400,000	W 595,000
1858	46°	114°	58°	354°	55°	735,000	+600,000	W 430,000
1859	78°	128°	62°	356°	76°	730,000	+710,000	W 170,000
1860	109°	142°	66°	357°	100°	710,000	+700,000	E 120,000
1861	139°	154°	71°	359°	124°	660,000	+545,000	E 370,000
1862	167°	167°	75°	1°	150°	610,000	+305,000	E 530,000
1863	194°	179°	79°	4°	179°	555,000	+ 10,000	E 555,000
1864	222°	192°	83°	5°	208°	510,000	—250,000	E 450,000
1865	251°	204°	88°	7°	238.5°	480,000	—410,000	E 245,000
1866	280°	215°	92°	10°	270°	460,000	—460,000	W 10,000
1867	311°	226°	96°	12°	302.5°	460,000	—390,000	W 245,000
1868	341°	238°	101°	14°	334°	445,000	—200,000	W 400,000
1869	18°	249°	105°	16°	2°	445,000	+ 10,000	W 445,000
1870	51°	260°	110°	19°	29°	410,000	+200,000	W 360,000
1871	82°	271°	114°	21°	66°	355,000	+295,000	W 200,000
1872	113°	282°	119°	23°	90°	315,000	+305,000	0 000,000
1873	143°	293°	124°	25°	128°	365,000	+205,000	E 160,000
1874	171°	304°	128°	28°	176°	230,000	+ 15,000	E 230,000

TABLE II (*Continued*).

Position of planets in heliocentric longitude on January 1st of each year					Direction and distance from sun to center of gravity of system		Sun's position relative to its apex and to center of gravity	
Year	Jup.	Sat.	Ura.	Nep.	Direction in heliocentric long.	Distance in miles	On the course, miles	Off the course, miles
1875	199°	316°	133°	30°	222°	250,000	—165,000	E 180,000
1876	226°	327°	137°	32°	265°	335,000	—335,000	E 30,000
1877	255°	339°	142°	34°	298°	435,000	—390,000	W 200,000
1878	284°	350°	142°	36°	323.5°	550,000	—330,000	W 445,000
1879	316°	3°	152°	38°	347°	645,000	—150,000	W 630,000
1880	348°	15°	156°	41°	10°	730,000	+120,000	W 720,000
1881	22°	28°	161°	43°	32°	785,000	+405,000	W 670,000
1882	55°	41°	166°	45°	53°	810,000	+640,000	W 485,000
1883	87°	54°	170°	48°	74°	810,000	+775,000	W 225,000
1884	118°	68°	175°	50°	95°	775,000	+770,000	E 60,000
1885	147°	81°	180°	52°	116°	715,000	+655,000	E 315,000
1886	175°	95°	185°	54°	138°	630,000	+425,000	E 470,000
1887	203°	109°	189°	57°	160°	530,000	+175,000	E 500,000
1888	230°	122°	194°	59°	187°	395,000	— 45,000	E 390,000
1889	259°	136°	199°	61°	217°	280,000	—165,000	E 225,000
1890	289°	149°	203°	63°	261°	185,000	—180,000	E 35,000
1891	321°	162°	208°	66°	330°	150,000	— 75,000	W 135,000
1892	354°	174°	213°	68°	25°	225,000	+ 95,000	W 200,000
1893	27°	187°	217°	70°	60°	310,000	+270,000	W 155,000
1894	60°	199°	222°	72°	88°	405,000	+405,000	W 10,000
1895	92°	210°	226°	75°	115°	480,000	+435,000	E 200,000
1896	122°	222°	231°	77°	140°	540,000	+340,000	E 410,000
1897	151°	233°	235°	79°	166°	590,000	+140,000	E 570,000
1898	179°	245°	240°	81°	190°	620,000	—110,000	E 605,000
1899	207°	256°	244°	84°	217°	630,000	—380,000	E 500,000
1900	235°	267°	249°	86°	243°	640,000	—570,000	E 300,000
1901	263°	278°	253°	88°	268°	645,000	—645,000	E 10,000
1902	294°	288°	257°	90°	296°	645,000	—585,000	W 280,000
1903	326°	300°	262°	92°	320°	640,000	—410,000	W 500,000
1904	359°	311°	266°	95°	347°	630,000	—140,000	W 620,000
1905	32°	322°	270°	97°	15°	570,000	+145,000	W 555,000
1906	65°	333°	274°	99°	42°	540,000	+355,000	W 400,000
1907	96°	346°	279°	101°	68°	490,000	+450,000	W 180,000
1908	126°	358°	283°	103°	93°	420,000	+425,000	E 25,000
1909	155°	10°	287°	106°	121°	340,000	+290,000	E 180,000
1910	183°	23°	291°	108°	150°	280,000	+135,000	E 235,000

TABLE III.

CHIEF ORDINATES OF PATH OF SUN DURING THREE GREAT YEAR PERIODS.

× Signifies sun crossing path of center of gravity.

Middle ordinates West—miles		Year		Middle ordinates East—miles
		× 1486.35		
540,000		1489		
	9.85	1493.24 ×		
		1495		120,000
		× 1496.2	10.83	
690,000		1500		
	13.75	1504.07 ×		
		1507		480,000
		× 1509.95	11.93	
425,000		1513		
	10.20	1516 ×		
		1518		230,000
		× 1520.15	12.75	
850,000		1524		
	12.05	1528.75 ×		
		1531		260,000
		× 1533.2	9.8	
360,000		1536		
	12.2	1538.55 ×		
		1542		615,000
		× 1545.4	13.75	
560,000		1549		
	10.6	1552.3 ×		
		1554		185,000
		× 1556	10.5	
560,000		1560		
	13.95	1562.8 ×		
		1566		655,000
		× 1569.95	11.85	
275,000		1572		
	10.05	1574.65 ×		
		1577		370,000
		× 1580	12.85	
720,000		1584		
	13.3	1587.5 ×		
		1590		410,000
		× 1593.3	9.8	
210,000		1595		
	11.9	1597.3 ×		
		1601		730,000
		× 1605.2	13.5	
445,000		1608		
	11.05	1610.8 ×		
		1613.5		350,000
		× 1616.25	10.5	
340,000		1619		
	14.10	1621.3 ×		
		1625		870,000
		× 1630.35	11.4	
70,000		1632		
	9.55	1632.7 ×		
		1637		530,000
		× 1639.9	13.75	
590,000		1643		
	12.75	1646.45 ×		
		1649		460,000
		× 1652.65	10.6	
250,000		1655		
	11.0	1657.05 ×		
		1660.5		550,000

Middle ordinates West—miles		Year		Middle ordinates East—miles
		× 1663.65	14.9	
715,000		1667		
	9.90	1671.95 ×		
		1673		400,000
		× 1673.55	9.95	
690,000		1678		
	14.35	1681.9 ×		
		1685		500,000
		× 1687.9	12.2	
450,000		1691		
	10.15	1694.1 ×		
		1696		210,000
		× 1698.05	12.2	
785,000		1702		
	13.71	1706.3 ×		
		1709		380,000
		× 1711.76	9.9	
260,000		1714		
	11.52	1716.2 ×		
		1720		630,000
		× 1723.28	14.0	
570,000		1727		
	10.87	1730.02 ×		
		1732		210,000
		× 1734.15	10.3	
470,000		1738		
	13.65	1740.5 ×		
		1744		690,000
		× 1747.8	12.3	
300,000		1750		
	10.03	1752.8 ×		
		1755		335,000
		× 1758.1	12.97	
650,000		1762		
	13.8	1765.05 ×		
		1768		530,000
		× 1771.9	9.75	
110,000		1774		
	11.2	1774.8 ×		
		1779		750,000
		× 1783.1	13.8	
430,000		1786		
	11.55	1788.6 ×		
		1792		420,000
		× 1794.65	10.45	
290,000		1797		
	13.15	1799.05 ×		
		1803		850,000
		× 1807.8	12.6	
200,000		1810		
	9.45	1811.65 ×		
		1815		375,000
		× 1817.25	13.05	
710,000		1821		
	12.95	1824.7 ×		
		1827		400,000
		× 1830.2	10.8	
350,000		1833		
	10.95	1835.5 ×		
		1838		420,000

Middle ordinates West—miles		Year		Middle ordinates East—miles
		× 1841.1	14.8	
820,000		1845		
	10.5	1850.3 ×		
		1851		30,000
		× 1851.6	9.3	
620,000		1856		
	14.35	1859.6 ×		
		1863		560,000
		× 1865.95	12.4	
440,000		1869		
	10.2	1872 ×		
		1874		230,000
		× 1876.15	11.8	
710,000		1880		
	14.05	1883.8 ×		
		1887		500,000
		× 1890.2	10.25	
200,000		1892		
	10.85	1894.05 ×		
		1898		600,000
		× 1901.05	13.81	
600,000		1904		
		1907.86 ×		
		1910		230,000

TABLE IV.

Moon's Orbit.

Number of course	Days of progress	Geocentric longitude	Moon's vector, in thousands of miles	Moon's departure west of earth, thousands of miles	Moon's departure east of earth, thousands of miles	Moon's latitude south of 90° point, thousands of miles. Plus	Moon's latitude north of 270° point, thousands of miles. Minus	Moon's latitude, total from 90° point, thousands of miles	Earth's progress at 1,594,600 miles a day for each two days =3,189,200, from 90°, moon's starting point, miles	Moon's progress along earth's path
0	0	90° 00′	221	.0		.0			221,520	0
1	2	118° 35′	222	10.6		2.5		2.5	3,410,720	3,213,720
2	4	146° 30′	226	18.9		7.0		9.5	6,599,920	6,472,920
3	6	173° 10′	233	23.2		9.8		19.3	9,789,120	9,762,120
4	8	198° 45′	240	22.7		10.5		29.8	12,978,320	13,056,320
5	10	213° 10′	246	17.9		8.9		38.7	16,167,520	16,335,520
6	12	247° 0′	250	9.8		6.3		45.0	19,356,720	19,584,720
7	14	271° 0′	252		0.3	2.2		47.2	22,545,920	22,795,920
8	16	295° 15′	250		10.7		2.6	44.6	25,735,120	25,959,120
9	18	321° 0′	246		18.9		7.0	37.6	28,924,320	29,078,320
10	20	347° 35′	239		23.3		10.3	27.3	32,113,520	32,164,520
11	22	15° 15′	232		22.3		11.25	16.1	35,302,720	35,241,720
12	24	43° 50′	225		16.2		9.5	6.6	38,491,920	38,335,920
13	26	72° 50′	221.5		6.6		5.6	1.0	41,681,120	41,469,120
14	27	90	221		.0		1.0	.0	43,788,383	43,566,863
1	2	3	4	5	6	7	8	9	10	11

TABLE V.

Number of course	Days of progress	Table of Mercury's Orbit						Total latitudes closed orbit Total latitude	Sun advancing 5 miles per second, 5 days=2,160,000 miles		Sun's speed at 16 miles, 5 days=6,912,000 miles		Sun's speed at 33 miles, 5 days=14,256,000 miles		Sun's speed at 69.4 miles, 5 days=6,000,000 miles	
		Heliocentric longitude	Vector	Departure west of sun	Departure east of sun	Mercury's latitude south of starting point			Sun's position	Mercury's latitude	Sun's position	Mercury's latitude	Sun's position	Mercury's latitude	Sun's position	Mercury's latitude
						Plus	Minus									
0	0	90° 00′	28,500,000	0		0		0	28,500,000	0	28,500,000	0	28,500,000	0	28,500,000	0
1	5	120° 19′	29,800,000	15,100,000		2,700,000		2,700,000	30,660,000	4,860,000	35,400,000	9,610,000	42,750,000	16,950,000	58,500,000	32,700,000
2	10	147° 16′	32,100,000	27,000,000		8,300,000		11,000,000	32,820,000	15,320,000	42,320,000	24,820,000	57,010,000	39,510,000	88,500,000	71,400,000
3	15	170° 19′	33,800,000	34,300,000		11,500,000		22,500,000	34,980,000	28,980,000	49,240,000	43,240,000	71,270,000	65,270,000	118,500,000	112,500,000
4	20	190° 00′	37,300,000	36,800,000		12,600,000		35,100,000	37,140,000	43,740,000	56,140,000	62,740,000	85,520,000	92,120,000	148,500,000	155,100,000
5	25	207° 11′	39,600,000	35,200,000		11,600,000		46,700,000	39,300,000	57,500,000	63,060,000	81,260,000	99,780,000	117,980,000	178,500,000	196,700,000
6	30	222° 40′	41,350,000	30,400,000		9,800,000		56,500,000	41,460,000	69,460,000	69,970,000	97,970,000	114,040,000	142,040,000	208,500,000	236,500,000
7	35	237° 05′	42,550,000	23,200,000		7,900,000		64,400,000	43,620,000	79,520,000	76,880,000	112,780,000	128,290,000	164,190,000	238,500,000	274,400,000
8	40	250° 56′	43,100,000	14,200,000		4,900,000		69,300,000	45,780,000	86,580,000	83,790,000	124,590,000	142,550,000	183,350,000	268,500,000	309,300,000
9	45	264° 41′	43,100,000	4,000,000		2,100,000		71,400,000	47,940,000	90,840,000	90,710,000	133,610,000	156,800,000	199,700,000	298,500,000	341,400,000
	47	270° 15′	42,900,000					71,400,000	50,100,000	0	93,470,000	136,370,000	0	0	316,500,000	351,500,000
10	3	278° 46′	42,300,000		6,500,000		1,100,000	70,300,000	52,260,000	94,060,000	97,620,000	139,420,000	171,060,000	212,286,000	328,500,000	370,300,000
11	8	293° 37′	41,000,000		16,400,000		4,300,000	66,000,000	54,420,000	91,920,000	104,530,000	142,030,000	185,000,000	222,820,000	358,500,000	396,000,000
12	13	309° 46′	39,100,000		25,000,000		7,400,000	58,600,000	56,580,000	86,680,000	111,440,000	141,540,000	199,570,000	229,670,000	388,500,000	418,600,000
13	18	327° 51′	36,700,000		31,000,000		10,400,000	48,200,000	58,740,000	78,440,000	118,360,000	138,060,000	213,830,000	233,530,000	418,500,000	438,200,000
14	23	348° 35′	33,900,000		33,350,000		12,900,000	35,300,000	60,900,000	67,700,000	125,270,000	132,070,000	228,080,000	234,880,000	448,500,000	455,300,000
15	28	12° 32′	31,400,000		30,600,000		13,700,000	21,600,000	63,060,000	56,160,000	132,180,000	125,280,000	242,340,000	235,440,000	478,500,000	471,600,000
16	33	40° 20′	29,300,000		22,400,000		12,100,000	9,500,000	65,220,000	46,220,000	139,100,000	120,100,000	256,600,000	237,600,000	508,500,000	489,500,000
17	38	71° 4′	28,400,000		9,200,000		7,900,000	1,600,000	67,380,000	40,480,000	146,000,000	119,100,000	270,850,000	243,950,000	538,500,000	511,600,000
18	41	90° 00′	28,500,000		0		1,600,000	0	68,650,000	40,150,000	150,100,000	121,600,000	279,290,000	250,790,000	556,260,000	527,760,000
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

PERNAU PUBLISHING CO.
423 HAYES STREET
SAN FRANCISCO, CAL.